A Mathematical Model of Electrostatic Precipitation (Revision 2)

Southern Research Inst.
Birmingham, AL

Prepared for

Industrial Environmental Research Lab.
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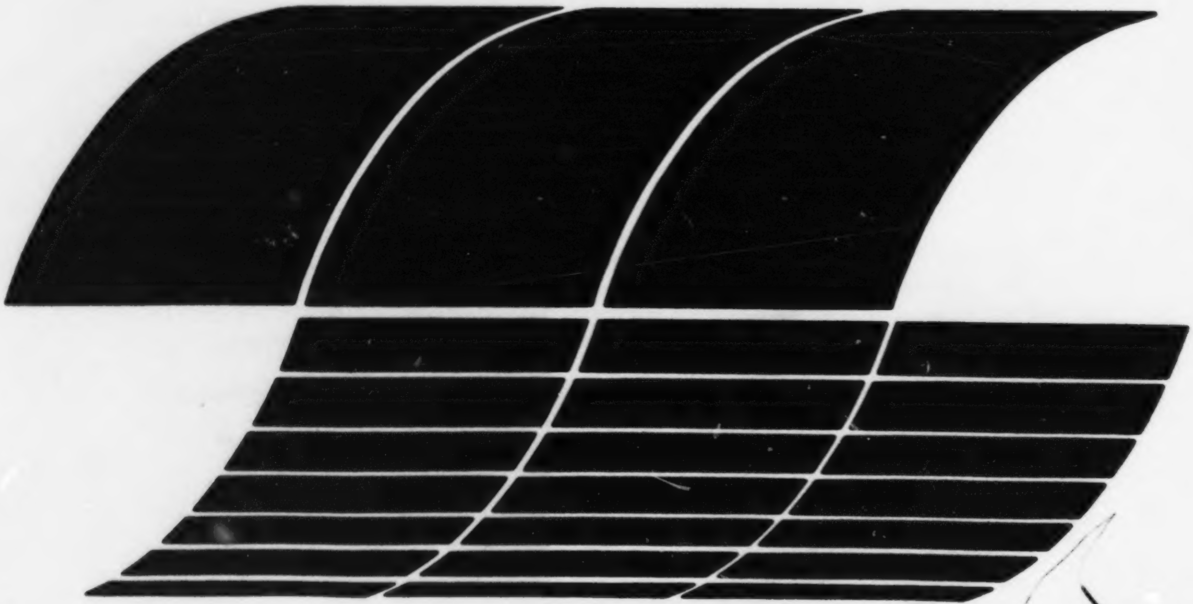

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The report describes modifications to the EPA/Southern Research Institute computer model of electrostatic precipitation (ESP). The modifications include a new semi-empirical approximation procedure for predicting electrical conditions in an ESP. Comparisons between the results from the approximation procedure and more exact procedures are presented. A new integration procedure for calculating particle charge is also presented. Complete FORTRAN listings of the revised ESP model and the new subprograms are provided. Example problems are included. The modified model requires significantly less computer time than does the earlier model. Comparisons of results obtained using the earlier and the modified models over a wide range of possible ESP geometries and electrical operating points indicate that for practical purposes the modified model can be used in place of the more rigorous earlier model.

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ABSTRACT

The objectives of this project were to develop analytic approximations for describing the electrical conditions in a wire-plate precipitator and to reduce the execution time required by the computer program which represents the model of electrostatic precipitation developed under the sponsorship of the Environmental Protection Agency.

In this report, a new semi-empirical, approximate theory for predicting electrical conditions is described. In the approximate theory, analytical expressions are derived for calculating voltage-current characteristics and electric potential, electric field, and space charge density distributions. Comparisons of numerical and approximate solutions over a wide range of possible precipitator geometries and electrical operating points indicate that for practical purposes the approximate theory can be used in lieu of the more rigorous numerical theory. This saves large amounts of computer time and makes possible hand calculator usage. Recent modifications to a previously described theory for numerically determining electrical conditions in wire-plate electrostatic precipitators are also discussed.

The numerical technique for performing the integration over the particle surface in the charging rate equation has been changed in order to decrease the computer time required. A Gaussian quadrature method which replaces a Simpson's rule method is presented. This modification results in a factor of 10 decrease in computer time required to perform the particle charging calculations while preserving essentially the same degree of accuracy.

The new and modified subroutines in the computer program are discussed. Detailed flow charts for each of these subroutines are provided. A listing of the computer code for each of these subroutines as well as for the entire program is given. Examples of various applications of the model are described and demonstrated in detail.

This report was submitted in partial fulfillment of Task 5 of Contract No. 68-02-2193 by Southern Research Institute under the sponsorship of the U.S. Environmental Protection Agency. This report covers a contract period from October 1, 1976 to December 31, 1978 and work was completed as of December 31, 1978.

CONTENTS

Disclaimer... iii
Abstract... iv
Figures.. vii
Tables... ix
Nomenclature... x
Metric Conversion Factors............................ xiii

1. Introduction...................................... 1
2. Conclusion.. 3
3. Recommendations................................... 4
4. Approximate Solution for Space Charge Limited Currents in Wire-Duct Precipitators.......................... 6
    Background....................................... 6
    Development of equations......................... 6
    Comparisons of approximate model with numercially integrated solutions and experimental observations.. 17
    Subroutine EFLD3................................. 23
    Subroutine CMAN.................................. 26
5. A Generalization of the Integration Scheme used in the Mathematical Model to Compute the Electrical Conditions in a Wire-Duct Precipitator.................. 43
    Background....................................... 43
    Development of equations......................... 44
    Boundary conditions.............................. 48
    Subroutine ELFD4................................. 49
    Subroutine output................................ 53
6. Gaussian Quadratures Integration for Computing Particle Charging Rates.............................. 67
7. Effects of the New Modifications on the Predictions of the Model.. 75
    Discussion....................................... 75
    Input data....................................... 83
    Machine-dependent aspects of the computer program.. 83
    Example cases and comparisons of the analytic approximations with predictions of the previous model.. 88

References... 101

Appendices.. 103

A. Listing of EFLD3...................................... 103
B. Listing of CMAN....................................... 109
C. Listing of EFLD4...................................... 112
D. Listing of OUTPUT..................................... 120
E. Listing of RATE....................................... 122
F. Complete Listing of the Computer Program.............. 124
G. Output Data for Example 1 (Revision 2)................ 179
H. Output Data for Example 1 (Revision 1)................ 194
I. Output Data for Example 2 (Revision 2)................ 209
J. Output Data for Example 2 (Revision 1)................ 225
K. Output Data for Example 3 (Revision 2)................ 241
L. Output Data for Example 3 (Revision 1)................ 257
M. Output Data for Example 4 (Revision 2)................ 273
N. Output Data for Example 4 (Revision 1)................ 290
O. Definition of Variables Used in the Program........... 307

FIGURES

Number		Page
1	Schematic showing a cross section of the wires and plates in an electrostatic precipitator...........	8
2	Schematic representing a cylindrical distribution of space charge and its associated images..........	10
3	Schematic illustrating a planar distribution of space charge and its associated surface charge.....	11
4	Current-voltage curves showing a comparison of the approximate model with the numerically integrated solution for geometrical parameters corresponding to the experimental conditions of Penney and Matick...	20
5	Comparison of theoretical potential profiles between a wire and plate with experiments of Penney and Matick.....................................	21
6	Comparison of theoretical potential profiles midway between wires with experiments of Penney and Matick...	22
7	Flow chart for subroutine EFLD3...................	27-37
8	Flow chart for subroutine CMAN....................	38-40
9	Schematic illustrating positions of integration grid points in the new integration scheme..........	46
10	Flow chart for subroutine EFLD4...................	54-61
11	Flow chart for subroutine OUTPUT..................	64-66
12	Flow chart for function subprogram RATE...........	71-73
13	Flow chart for simplified logic of the entire program..	76-82
14	Comparison of fractional collection efficiencies computed from Revision 1 of the model using electrical conditions measured in a laboratory precipitator with those computed from Revision 2 of the model using the approximations....................	90

Number Page

15 Comparison of fractional collection efficiencies computed from Revision 1 of the model using theoretical current-voltage calculations with those computed from Revision 2 using the approximate electrical calculations.............................. 92

16 Comparison of fractional collection efficiencies computed from Revision 1 of the model using the estimation procedures and the parameters in Example 2 with the corresponding calculations in Revision 2 using the approximations.............. 97

17 Comparison of fractional collection efficiencies computed from Revision 1 of the model using measured electrical conditions from a full-scale, cold-side precipitator with those computed from Revision 2 of the model using the approximations............... 99

TABLES

Number		Page
1	Comparison of Approximation and Numerically Integrated Solution	18
2	Charge on Particles Computed by Different Integration Methods	68
3	Core Requirements for Various Segements of the Computer Program	85
4	Input Data Cards for Example 1	91
5	Input Data Cards for Example 2	93
6	Input Data Cards for Example 3 (Revision 2)	95
7	Input Data Cards for Example 3 (Revision 1)	96
8	Input Data Cards for Example 4	98

NOMENCLATURE

$V_s(x,y)$	The electrostatic potential at a point (x,y) (V)
V_{st}	A constant determined by the amount of charge on a wire (V)
x	Coordinate position measured toward the plate with the corona wire as origin (m)
y	Coordinate position measured parallel to the plate with the corona wire as origin (m)
S_x	Wire-to-plate spacing (m)
S_y	Half wire-to-wire spacing (m)
E_0	The electric field at the surface of the wires (V/m)
a_0	Radius of the discharge wires (m)
V	Potential (V)
J	Current density (A/m^2)
b	Ion mobility (m^2/V-sec)
ε_0	Permittivity of vacuum (A sec/Vm)
R	Distance from the wire at which the solutions are to be matched (m)
V_1	A constant determined by the amount of space charge in a cylinder (V)
$V(x,y)$	Potential at the point (x,y)(V)
V_0	Constant used for matching the potentials at x=R (V)
ζ	Constant occurring in the potential expression
δ	Constant occurring in the potential expression
γ	Constant occurring in the potential expression

$\rho(x,y)$	Charge density at point (x,y) (C/m^3)
K_1	A constant used to match the charge density profiles at X=R
f_1	Empirical factor used in charge density calculation
f_2	Empirical factor used in charge density calculation
f_3	Empirical factor used in charge density calculation
F	Factor which corrects for overlapping of space charge cylinders
E	Electric field (V/m)
E_x	x-component of the electric field (V/m)
E_y	y-component of the electric field (V/m)
ax	Spacing of integration points along the x-direction (m)
ay	Spacing of integration points along the y-direction (m)
α	Parameter in the equation for charge density (C/m^3)
β	Parameter in the equation for charge density (C^2/m^6)
ΔV	Potential drop across the corona region (V)
VW	Potential at the surface of the wire (V)
ECOR	Average field required to drive the corona (V/m)
RC	Radius of the corona (m)
AC	Radius of the wire (m)
q	Instantaneous charge on a particle (C)
t	Time (sec)
N_0	Free ion density (m^{-3})
e	Electronic charge (C)
q_s	Saturation charge due to field charging (C)
a	Particle radius (m)
$\tilde{v}$	Mean thermal speed of ions (m/sec)

θ_0	Arccos (q/q_s)
r_0	Radial distance along θ at which the radial component of the total electric field is zero (m)
k	Boltzmann's constant (J/°K)
T	Absolute temperature (°K)
K	Dielectric constant of the particle
E_a	Average electric field between the electrodes (V/m)
θ	Azimuthal angle in a spherical coordinate system with origin at the center of the particle (radians)
$f(\theta)$	Function to be integrated
$F(t)$	Function to be integrated
$A_k (k=0,1,\ldots,n)$	Gaussian weights
$t_k (k=0,1,\ldots,n)$	Roots of Legendre polynomials

METRIC CONVERSION FACTORS

To Convert From	To	Multiply by
grams/ft^3	kg/m^3	0.00229
ft	m	0.3048
ft^2	m^2	0.0929
in	m	0.0254
ft^3/min	m^3/sec	0.000472
ft/sec	m/sec	0.3048
°F	°K	$(°F+459) \times \frac{1}{1.8}$

SECTION 1

INTRODUCTION

The EPA/SoRI computer model of electrostatic precipitation was first published in 1975.[1] Revision 1 of the model[2,3] was published in 1978. This computer model has been used by many individuals involved in electrostatic precipitation technology. In general, the various users have found the model useful. However, many users have commented that the time required to run the model was excessive.

This report describes revisions to the model that greatly reduce the computer time required with only a slight loss in accuracy. The revisions described in this report consist of:

1. A new procedure for calculating electric fields and V-I curves using an approximate analytic solution and,

2. A new procedure for calculating particle charge.

The revisions affect the internal workings of the program, but do not affect the model-user interface. The data input requirements and the format for the data are the same in this revised model as the data in the original model.

The revisions may be implemented either by adding the new procedures to an existing version of the model or by obtaining a tape copy of the complete revised model from NTIS*.

This report does not replace the previous model reports but is intended to supplement them. The user is urged to obtain and read references 2 and 3 before using Revision 2 of the model. This report provides a complete description of the new procedures including their effect on execution time and accuracy.

A second, new procedure for calculating electric fields and V-I curves is also described in this report. This procedure has not been incorporated into the working version of the model because the slight increase in accuracy gained by its use does not justify the long computing time required to use it.

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*National Technical Information Service, Springfield, Virginia 22161.

The report contains sample problems showing how to use the new procedures. Complete FORTRAN listings for all new procedures and the revised model are included in appendices of this report. This revised model is described as Revision II Aug. 1979.

Please note that this computer program is distributed on an "As Is" basis without warranty by either the United States Environmental Protection agency or Southern Research Institute. We are, however, interested in your comments--especially those that will allow us to improve the model. If you have comments or suggestions, please contact either the authors or the EPA project officer.

SECTION 2

CONCLUSIONS

The version of the mathematical model of electrostatic precipitation presented in this report offers an option which requires significantly less time to perform a calculation than does the previous version because of two factors. First, the time required to perform the charge calculation has been decreased through the use of Gaussian quadratures instead of the Simpson's rule integration. There is little loss in accuracy (on the order of 2% maximum) due to the faster charge calculation. Second, the time required to run the program has been further decreased by the use of analytic approximations to the solutions of the electrical equations. For practical ranges of operating parameters, the inaccuracies introduced by these approximations are within acceptable limits. The combination of these two modifications to the program decreases the computation time by about a factor of 10 from that required by the previous version of the model.

The numerical method used to compute the electrical solutions in the previous version of the model has been modified to accept variable step sizes in the discretization scheme. This new numerical method gives rise to improved accuracy in some cases, but requires more execution time than is justified by its use. Consequently, this new numerical scheme has not been incorporated into the computer program.

For current users of the model, this new version can be used in exactly the same manner and with the same input data as before with the only difference being that the particle charging will be done using the Gaussian quadratures rather than the Simpson's rule integration. In order to convert a working version of the program to the new revised form, it is necessary to replace subprograms CMAN and RATE by the new versions listed in Appendices B and E, respectively. The new subprogram EFLD3 listed in Appendix A must also be added. In addition to these subprograms, a few statements must be added to the main program. These modifications may be seen in the listing of the program in Appendix F. The data block subprogram used to initialize certain variable arrays may not be necessary with some computers. A tape copy of the complete program is available from NTIS (see footnote in the Introduction). Detailed instructions for using the model must still be obtained from Revision 1 of the model report.

SECTION 3

RECOMMENDATIONS

Although the mathematical model of electrostatic precipitation presented in this report represents a significant improvement over the previous version, more work still needs to be performed in order to improve the fundamental basis and user oriented aspects of the model.

With respect to the fundamental basis of the model, it is recommended that the following research be pursued:

1. Theoretical and experimental studies of the effects of particles on the electrical conditions should be continued in order to better describe the effect on the electric field distribution.

2. Theoretical and experimental studies of electrical breakdown mechanisms in the collected particulate layer should be given greater emphasis in an attempt to acquire the capability of theoretical prediction of when electrical breakdown will ensue for a given value of dust resistivity.

3. Since the model underpredicts field-measured collection efficiencies for fine particles without the use of empirical correction factors, theoretical and experimental studies should be continued in order to remove the empiricism or to explain the discrepancy. These studies should include a reevaluation of the theories presently used in the model and an examination of those effects which are presently neglected such as particle charging near corona wires and phenomena due to the gas flow field. There is evidence[4] that free electrons may play a role in particle charging in negative coronas for temperatures of 150°C to 350°C. A charging theory which accounts for this effect is needed.

4. The mathematical model should be restructured to take into account time-dependent effects. The effects due to the growth of the particulate layer and the rapping schedule should be included as a function of time. Although the empirical procedure employed in the present version of the model represents a useful interim technique for estimating the effects due to rapping reentrainment in precipitators, it does not describe the temporal and dynamic aspects of the rapping process. The inclusion of time-dependent effects is necessary in order to optimize the electrical operating conditions and the rapping schedule and intensity.

The above research is needed in order to make the model independent of empiricism and of the experience and judgment of the user.

With respect to the user oriented aspects of the model, it is recommended that the following work be performed:

1. Alternative numerical techniques need to be investigated and implemented in order to make the computer program run significantly faster.

2. Although the charging calculation has been speeded up considerably by the Gaussian quadratures, the speed could be increased even more. As can be seen from Figure 2 of Reference 4, the particle charge distribution could be represented to a considerable degree of accuracy by two simple power laws in the two regions separated by a particle radius of about one micrometer. To determine the two power relationships it would only be necessary to compute the charge for three particle sizes. The charge on the remaining particles would be computed from the appropriate relationship. For a calculation with 15 particle sizes, this approximation should decrease the time for computing the charge on the particles by about a factor of 5.

3. Procedures which edit the input data should be implemented.

4. Documentation of the computer program needs to be included in abbreviated form in the computer card deck.

The above work is needed in order to continue the transition in which the model is transformed from a research tool to one which is more practical to use.

SECTION 4

APPROXIMATE SOLUTION FOR SPACE CHARGE LIMITED CURRENTS IN WIRE-DUCT PRECIPITATORS

BACKGROUND

In order to model the behavior of an electrostatic precipitator, it is necessary to compute the electric field and potential in the interelectrode space. In the mathematical model of precipitation developed by Southern Research Institute under the direction of the Environmental Protection Agency's Particulate Technology Branch of the Industrial Research Laboratory at Research Triangle Park, a relaxation method is used to solve Poisson's equation coupled with the charge transport equation. This numerical procedure requires a great deal of computer time. The computer time required could be greatly reduced if an analytic solution to this system of equations were available. Since an exact solution does not seem probable, an approximate solution is appropriate. An analytic solution is further desirable because it would significantly simplify some of the difficulties of incorporating the space-charge effects of particles into the mathematical model.

DEVELOPMENT OF EQUATIONS

Using a conformal mapping technique, Cooperman[5] demonstrated that the electrostatic potential $V_s(x,y)$ in the interelectrode space of a wire-duct precipitator with 2N+1 corona wires can be written as

$$V_s(x,y) = V_{st} \sum_{m=-N}^{N} \ln \left[\frac{\cosh \pi (y-2ms_y)/2s_x - \cos(\pi x/2s_x)}{\cosh \pi (y-2ms_y)/2s_x + \cos(\pi x/2s_x)} \right] \quad (1)$$

with

$$V_{st} = - \frac{s_x \quad E_0}{\pi \,\mathrm{Sin}(\pi a_0/2s_x)} \left\{ \sum_{m=-N}^{N} \frac{\cosh\,(m\pi s_y/s_x)}{\cosh^2(m\pi s_y/s_x) - \cos^2(\pi a_0/2s_x)} \right\}^{-1} \quad (2)$$

where

E_0 = the electric field at the surface of the wires (V/m),

a_0 = radius of the wires (m),

s_x = wire-to-plate spacing (m),

s_y = half wire-to-wire spacing (m),

x = the displacement from a wire toward the plate (m),

y = the displacement from a wire in the direction parallel to the plate (m),

2N+1 = the number of corona wires.

Figure 1 shows the region of the precipitator that is of interest. The origin is taken at the wire, while x is measured toward the plate and y is measured toward an adjacent wire. When a current flows in the presence of space charge, equation (1) does not apply. Equation 1 can be used to advantage, however, in obtaining an approximate solution for the dynamic case in which the current is space charge limited. Suppose a steady current flows under the action of an applied potential for the case illustrated in Figure 1. The electrical configuration will be simplified by using the principle of superposition. Each of the contributions to the potential will be separated and described below.

First consider just the electrodes. For a negative corona, the wire will be charged negatively while the plate will be charged positively. The charge on the plate will exceed the magnitude of the charge on the wire by an amount equal to the quantity of negative space charge in the interelectrode space. The negative charge on the wires coupled with an equal amount of positive charge on the two plates constitutes a situation similar to the static case of Cooperman. Mathematically, the solution for this case is identical in form to the electrostatic case, but the amount of charge on the wires is not necessarily the same as when the current is zero. Suppose that a small increase in the electric field at the surface of the wire gives rise to a large increase in the number of electrons emitted from the wire during the corona discharge. The field at the surface of the wire when a current flows, then would be nearly the same as Peek's value of the field required for corona start. In this case, the charge on the wire will be computed in terms of Peek's condition[6] on the field at the wire. The static-like solution would then be completely determined. It remains to specify the contributions to the potential from the negative space charge coupled with an equal amount of positive charge on the plates and from the corona discharge process itself. These last contributions must be approximated since closed-form solutions are not available.

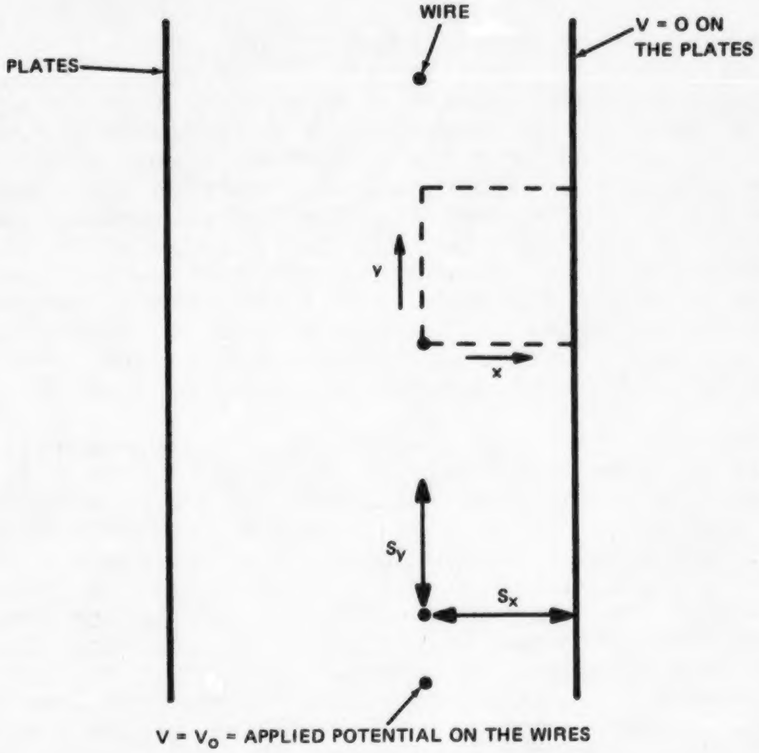

Figure 1. Schematic showing across section of the wires and plates in an electrostatic precipitator.

The primary considerations to be used in obtaining approximate solutions will be the apparent symmetry of the arrangement. For example, the equipotential lines near the discharge wires look very much like those for a wire-cylinder geometry,[5] while the equipotential lines near the plates look very much like those for a parallel plate geometry.[7,8] Using these observations, it will be assumed that the space charge near the wire is distributed in the same manner as that in a wire cylinder geometry, and that the space charge near the plate is distributed in the same manner as that in a parallel plate geometry. These two space charge distributions along with their associated surface charges are illustrated in Figures 2 and 3, respectively. Potentials computed from these two geometries will be matched at some point (x=R, where R is the radius of the cylinder of charge) in the interelectrode space to yield continuity of potential. The electric field is also required to be continuous at the matching point.

The contributions to the potential by the corona region will be assumed to be small. According to Loeb,[9] the potential drop across the ionization region of a corona is essentially independent of the current. The effect of the corona on the field at the surface of the wire at corona start is included in the measurement of Peek's field since the measurement is made with a minimum steady current. Based on the above considerations, it is assumed that the only role which the corona plays is to supply ions to carry the current in the interelectrode space.

Negative charge distributed uniformly in planes parallel to the plate which has an equal amount of positive charge, as shown in Figure 3, will yield a potential V given by

$$V = -\frac{2}{3}\left(\frac{2J}{b\varepsilon_0}\right)^{\frac{1}{2}}\left[(s_x - R)^{3/2} - (x - R)^{3/2}\right], \qquad (3)$$

where

J = current density (A/m^2),

b = ion mobility ($m^2/V\text{-sec}$),

ε_0 = permittivity of gas (approximately 8.85×10^{-12} A sec/Vm), and

R = point at which the solutions are to be matched.

In this same region, near the plate, the potential produced by the cylinder of negative charge coupled to an equal amount of positive charge on the plates must be taken into account. For points which lie outside the cylinder of charge shown in Figure 2, the solution will be the same as for a line of charge at the center with the same quantity of charge as contained in the cylinder. This problem has a solution similar to the electrostatic

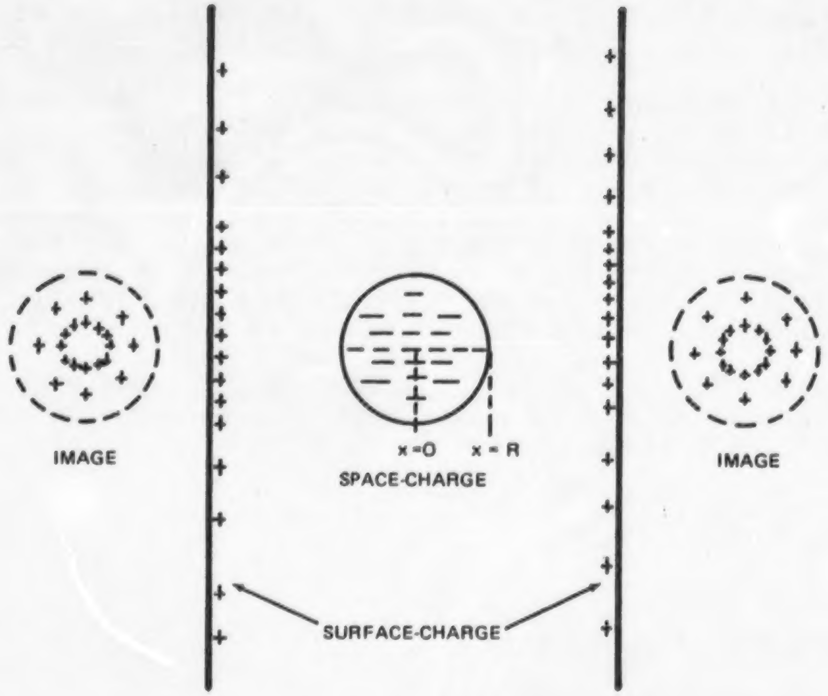

Figure 2. Schematic representing a cylindrical distribution of space charge and its associated images.

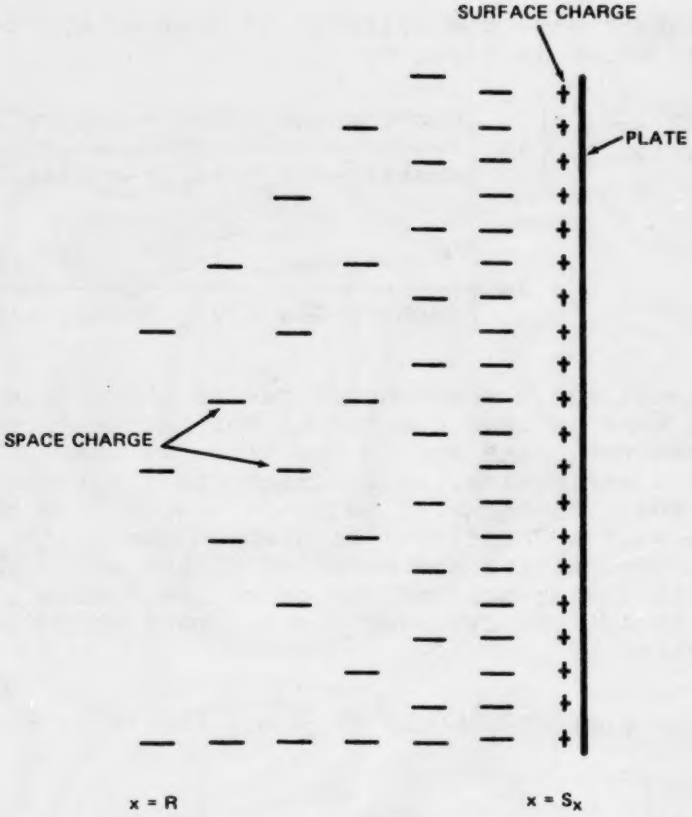

Figure 3. Schematic illustrating a planar distribution of space charge and its associated surface charge.

case mentioned before. When all 2N+1 wires are considered, the contribution to the potential for x greater than R will be

$$V = V_1 \sum_{m=-N}^{N} \ln \left[\frac{\cosh\pi(y-2ms_y)/2s_x - \cos(\pi x/2s_x)}{\cosh\pi(y-2ms_y)/2s_x + \cos(\pi x/2s_x)} \right] , \qquad (4)$$

where V_1 depends on the amount of charge in the cylinder.

At points inside the cylinder of charge, the potential due to the other wires is given by

$$V = V_1 \sum_{m=1}^{N} \left\{ \ln \left[\frac{\cosh\pi(y-2ms_y)/2s_x - \cos(\pi x/2s_x)}{\cosh\pi(y-2ms_y)/2s_x + \cos(\pi x/2s_x)} \right] + \ln \left[\frac{\cosh\pi(y+2ms_y)/2s_x - \cos(\pi x/2s_x)}{\cosh\pi(y+2ms_y)/2s_x + \cos(\pi x/2s_x)} \right] \right\} . \qquad (5)$$

To this we must add the potential due to the charge inside the cylinder as well as that due to the two images shown in Figure 2. To obtain the potential due to the negative space charge in the cylindrical distribution, we subtract the electrostatic solution for a wire and cylinder with no space charge from the solution of the same wire and cylinder with space charge.[10] The two images are used to account for the coupling of the space charge in the cylinder with the associated charge on the plates. The potential at a point inside the cylinder due to space charge and the two images is given by

$$\begin{aligned} V(x,y) = V_0 - a_0 E_0 \Bigg\{ & \left(\frac{\zeta-1}{2}\right) \ln \left(\frac{x^2+y^2}{R^2}\right) + (1+\delta(x^2+y^2-a_0^2))^{\frac{1}{2}} - \gamma \\ & + \zeta \ln \left[\frac{\zeta+\gamma}{\zeta + (1+\delta(x^2+y^2-a_0^2))^{\frac{1}{2}}} \right] \qquad (6). \\ & - \left(\frac{\gamma-1}{4}\right) \left[\ln \left(\frac{x^2+y^2+4s_x(s_x-x)}{R^2+4s_x(s_x-R)} \right) + \ln \left(\frac{x^2+y^2+4s_x(s_x+x)}{R^2+4s_x(s_x+R)} \right) \right] \Bigg\} , \end{aligned}$$

where

$\delta = 2Js_y/\pi\varepsilon_0 b a_0{}^2 E_0{}^2$,

$\zeta = (1 - \delta a_0{}^2)^{\frac{1}{2}}$,

$\gamma = (1 + \delta(R^2 - a_0{}^2))^{\frac{1}{2}}$,

E_0 = electric field at the wire,

a_0 = radius of the wire.

The constant V_0 is to be chosen to match the solutions at the point x=R.

In the event that the cylindrical symmetry extends all the way to the plate, the condition that the potential be zero on the plate will be met rigorously only for y=0. This limitation can be removed in an empirical manner by adding y^2 to a few terms. This would have little effect near the wire, but allows the boundary conditions to be met by a slight modification to the cylindrical solution. The potential at a point inside the cylinder (x<R) due to space charge and the two images then becomes

$$\begin{aligned}
V(x,y) = \; & V_0 - a_0E_0 \Bigg\{ \left(\frac{\zeta-1}{2}\right) \ln \left(\frac{x^2+y^2}{R^2+y^2}\right) \\
& + (1 + \delta(x^2+y^2-a_0{}^2))^{\frac{1}{2}} - (1 + \delta(R^2+y^2-a_0{}^2))^{\frac{1}{2}} \\
& + \zeta \ln \left[\frac{\zeta + (1+\delta(R^2+y^2-a_0{}^2))^{\frac{1}{2}}}{\zeta + (1+\delta(x^2+y^2-a_0{}^2))^{\frac{1}{2}}}\right] \\
& - \left(\frac{\gamma-1}{4}\right) \left[\ln \left(\frac{x^2+ y^2+4s_x(s_x-x)}{R^2+ y^2+4s_x(s_x-R)}\right) + \ln \left(\frac{x^2+y^2+4s_x(s_x+x)}{R^2+y^2+4s_x(s_x+R)}\right)\right] \Bigg\} \; .
\end{aligned} \tag{7}$$

This solution not only yields a constant potential on the plane x=R, but also leads to x and y components of electric field which satisfy the necessary boundary conditions imposed on the solution by symmetry. Specifically, the x-component of electric field must vanish in the plane of the wires, while the y-component must vanish at the plates and at the two planes represented by dashed lines connecting the plane of the wires with the plates in Figure 1. The x and y components of the electric field are computed by differentiating the potential expressions. The constant V_0 is chosen to match the potentials at x=R, and V_1 is chosen to match the x-component of the electric field at x=R, y=0. After the matching is carried out for both the potential and electric field we obtain

$$\begin{aligned}
V(x,y) = & -\frac{2}{3} \left(\frac{2J}{b\varepsilon_0}\right)^{\frac{1}{2}} (s_x-R)^{3/2} + V_1 \ln \left[\frac{1 - \cos(\pi R/2s_x)}{1 + \cos(\pi R/2s_x)}\right] \\
& - a_0E_0 \Bigg\{ \left(\frac{\zeta-1}{2}\right) \ln \left(\frac{x^2+y^2}{R^2+y^2}\right) + (1 + \delta(x^2+y^2-a_0{}^2))^{\frac{1}{2}} \\
& - (1+\delta(R^2+y^2-a_0{}^2))^{\frac{1}{2}} + \zeta \ln \left[\frac{\zeta+(1+\delta(R^2+y^2-a_0{}^2))^{\frac{1}{2}}}{\zeta+(1+\delta(x^2+y^2-a_0{}^2))^{\frac{1}{2}}}\right]
\end{aligned}$$

$$- \left(\frac{\gamma-1}{4}\right) \left[\ln \left(\frac{x^2+y^2+4s_x(s_x-x)}{R^2+y^2+4s_x(s_x-R)}\right) + \ln \left(\frac{x^2+y^2+4s_x(s_x+x)}{R^2+y^2+4s_x(s_x+R)}\right) \right] \Bigg\}$$

$$+ V_1 \sum_{m=1}^{N} \left\{ \ln \left[\frac{\cosh\pi(y-2ms_y)/2s_x - \cos(\pi x/2s_x)}{\cosh\pi(y-2ms_y)/2s_x + \cos(\pi x/2s_x)} \right] \right.$$

$$\left. + \ln \left[\frac{\cosh\pi(y+2ms_y)/2s_x - \cos(\pi x/2s_x)}{\cosh\pi(y+2ms_y)/2s_x + \cos(\pi x/2s_x)} \right] \right\}$$

$$+ V_{st} \sum_{m=-N}^{N} \ln \left[\frac{\cosh\pi(y-2ms_y)/2s_x - \cos(\pi x/2s_x)}{\cosh\pi(y-2ms_y)/2s_x + \cos(\pi x/2s_x)} \right] \qquad (8)$$

$$E_x(x,y) = a_0 E_0 \left\{ \frac{x}{x^2+y^2} \left[(1+\delta(x^2+y^2-a_0{}^2))^{\frac{1}{2}} - 1 \right] \right.$$

$$\left. - \left(\frac{\gamma-1}{2}\right) \left[\frac{x-2s_x}{x^2+y^2+4s_x(s_x-x)} + \frac{x+2s_x}{x^2+y^2+4s_x(s_x+x)} \right] \right\}$$

$$- \frac{V_1\pi}{s_x} \operatorname{Sin}(\pi x/2s_x) \sum_{m=1}^{N} \left\{ \frac{\cosh\pi(y-2ms_y)/2s_x}{\cosh^2\pi(y-2ms_y)/2s_x - \cos^2(\pi x/2s_x)} \right.$$

$$\left. + \frac{\cosh\pi(y+2ms_y)/2s_x}{\cosh^2\pi(y+2ms_y)/2s_x - \cos^2(\pi x/2s_x)} \right\}$$

$$- \frac{V_{st}\pi}{s_x} \operatorname{Sin}(\pi x/2s_x) \sum_{m=-N}^{N} \left\{ \frac{\cosh\pi(y-2ms_y)/2s_x}{\cosh^2\pi(y-2ms_y)/2s_x - \cos^2(\pi x/2s_x)} \right\} \qquad (9)$$

$$E_y(x,y) = a_0 E_0 \left\{ \left(\frac{y}{x^2+y^2}\right) \left[(1+\delta(x^2+y^2-a_0{}^2))^{\frac{1}{2}} - 1 \right] \right.$$

$$- \left(\frac{y}{R^2+y^2}\right) \left[(1+\delta(R^2+y^2-a_0{}^2))^{\frac{1}{2}} - 1 \right]$$

$$- \left(\frac{\gamma-1}{2}\right) \left[\frac{y}{x^2+y^2+4s_x(s_x-x)} + \frac{y}{x^2+y^2+4s_x(s_x+x)} - \frac{y}{R^2+y^2+4s_x(s_x-R)} - \frac{y}{R^2+y^2+4s_x(s_x+R)}\right]\Bigg\}$$

$$- \frac{V_1\pi}{s_x} \cos(\pi x/2s_x) \sum_{m=1}^{N} \left\{\frac{\text{Sinh}\pi(y-2ms_y)/2s_x}{\cosh^2\pi(y-2ms_y)/2s_x - \cos^2(\pi x/2s_x)} + \frac{\text{Sinh}\pi(y+2ms_y)/2s_x}{\cosh^2\pi(y+2ms_y)/2s_x - \cos^2(\pi x/2s_x)}\right\}$$

$$- \frac{V_{st}\pi}{s_x} \cos(\pi x/2s_x) \sum_{m=-N}^{N} \left\{\frac{\text{Sinh}\pi(y-2ms_y)/2s_x}{\cosh^2\pi(y-2ms_y)/2s_x - \cos^2(\pi x/2s_x)}\right\} \qquad (10)$$

for x < R, and

$$V(x,y) = -\frac{2}{3}\left(\frac{2J}{b\varepsilon_0}\right)^{1/2}\left[(s_x-R)^{3/2} - (x-R)^{3/2}\right]$$

$$+ (V_{st}+V_1) \sum_{m=-N}^{N} \ln \left[\frac{\cosh\pi(y-2ms_y)/2s_x - \cos(\pi x/2s_x)}{\cosh\pi(y-2ms_y)/2s_x + \cos(\pi x/2s_x)}\right] \qquad (11)$$

$$E_x(x,y) = -\left(\frac{2J}{b\varepsilon_0}\right)^{1/2} (x-R)^{1/2}$$

$$- (V_{st}+V_1)\pi/s_x \,\text{Sin}(\pi x/2s_x) \sum_{m=-N}^{N} \left[\frac{\cosh\pi(y-2ms_y)2s_x}{\cosh^2\pi(y-2ms_y)/2s_x - \cos^2(\pi x/2s_x)}\right] \qquad (12)$$

$$E_y(x,y) = -(V_{st}+V_1)\pi/s_x \cos(\pi x/2s_x) \sum_{m=-N}^{N} \left[\frac{\text{Sinh}\pi(y-2ms_y)/2s_x}{\cosh^2\pi(y-2ms_y)/2s_x - \cos^2(\pi x/2s_x)}\right] \qquad (13)$$

for x > R, where

$$V_1 = \frac{a_0E_0(\gamma-1)s_x}{\pi R}\,\mathrm{Sin}(\pi R/2s_x)\left\{1 - \frac{R}{2}\left[\frac{R-2s_x}{R^2+4s_x(s_x-R)} + \frac{R+2s_x}{R^2+4s_x(s_x+R)}\right]\right\}. \tag{14}$$

The charge density profiles corresponding to the above functions can be computed from the two separate symmetries used in this model. For cylindrical symmetry the charge density is given by

$$\rho(x,y) = -\ (2J/ba_0E_0)\ (1+\delta(x^2+y^2-\ a_0{}^2))^{-\frac{1}{2}} \tag{15}$$

while, for rectangular symmetry the charge density is

$$\rho(x,y) = -\ (\varepsilon_0J/2b)^{\frac{1}{2}}\ (x-R+K_1)^{-\frac{1}{2}}\ , \tag{16}$$

where K is a constant which is added to avoid a singularity in the charge density at x=R. The constant K_1 is to be chosen to match the two charge density profiles at x=R, y=0. Because the charge distributions are distorted considerably by the charge on the plates, it is necessary to use empirical correction factors to improve the agreement of these charge profiles with the numerically integrated solutions. One such correction term can be generated by differentiating the image terms in equation (8) and then replacing R^2 by x^2. With correction factors we obtain

$$\rho(x,y) = -\ (2J/ba_0E_0)\ (1+\delta(x^2+y^2-a_0{}^2))^{-\frac{1}{2}}\ f_1+\ f_2 \tag{17}$$

for x < R and

$$\rho(x,y) = -\ (\varepsilon_0J/2b)^{\frac{1}{2}}\ (x-R+K_1)^{-\frac{1}{2}}\ \ f_3 \tag{18}$$

for x > R where

$$f_1 = \{[1+0.16\ y/s_y]\ [1+2.2\ (y/s_y)^9]\}^{-1}\ , \tag{19}$$

$$f_2 = 0.45\ \varepsilon_0a_0E_0\ [(1+\delta(x^2+y^2-a_0{}^2))^{\frac{1}{2}} - 1]$$

$$\left[\frac{R^2-y^2+4s_x(s_x-R)}{(R^2+y^2+4s_x(s_x-R))^2}+\frac{R^2-y^2+4s_x(s_x+R)}{(R^2+y^2+4s_x(s_x+R))^2}\right]\ , \tag{20}$$

and

$$f_3 = \{[1+0.75\ y/s_y]\ [1+2.2\ (y/s_y)^9]\}^{-1}\ . \tag{21}$$

Equations (8) through (21) completely characterize the approximate model. Although the charge profiles have not been optimized from an empirical standpoint, they are adequate for most purposes. It should be pointed out that the charge density profiles are the least important of all the functions described in this model. The electrical behavior of precipitators is characterized primarily by the potential and the electric field. As will be shown in the next section, the potential and electric field expressions of this approximate model predict the operating conditions of wire-duct precipitators quite well.

COMPARISONS OF APPROXIMATE MODEL WITH NUMERICALLY INTEGRATED SOLUTIONS AND EXPERIMENTAL OBSERVATIONS

In general, the agreement of the approximate model with the numerically integrated solution is found to be quite good. In all the cases described here, the approximate model was compared with the results of the numerical integration scheme described in Section 5 of this report. Table 1 summarizes the comparison between the approximate model and the numerical solution for a wide range of geometrical parameters and current densities. Columns 1, 2, and 3 list the corona wire radius, the wire-to-plate spacing, and the half wire-to-wire spacing, respectively. While more combinations of geometrical parameters in this table are typical of industrial electrostatic precipitators, examples of both close and wide wire spacing are shown. Both large and small corona wires are represented and a considerable range of plate spacings is given. Column 4 lists the current densities that were used. The values of current density were chosen to represent both moderate and relatively high space charge situations. Column 5 gives the percent difference in applied voltage for the approximate and numerically integrated solutions. Column 6 gives the percent difference in the average electric field at the plate. Column 7 gives the maximum percent difference in the potential profiles. Columns 8 and 9 give the maximum percent differences in the x-component and the y-component respectively of the electric field profiles. Column 10 gives the maximum percent difference in the charge density profiles. For a comparison with average errors, consider the parameters shown in row 3 of Table 1. For these parameters, which are typical of electrostatic precipitators in the United States, the average difference in the approximate and integrated potential profiles is 1 percent. The average difference in the x-component of the electric fields is 2 percent while the average difference in the y-components is 24 percent. The average difference in the charge density profiles is 8 percent. It can be observed that the average differences in the approximate and integrated solutions are appreciably smaller than the corresponding maximum values listed in Table 1. The average errors stated for this particular set of parameters are representative of those occurring throughout the table.

In the approximate model, one is free to choose the position (x=R) at which to match the functions derived from the two different symmetries. For the calculations shown in Table 1, R was chosen to be $0.975s_x$. This corresponds to using only a few

Table 1. COMPARISON OF APPROXIMATION AND NUMERICALLY INTEGRATED SOLUTION

Wire Radius (10^{-3} m)	Wire Plate Distance (m)	Half Wire-to-wire Distance (m)	Current Density (nA/cm^2)	Percent Difference In Applied Voltage	Percent Difference In Field At The Plate	Max. % Difference In Potential Profiles	Max. % Difference In x-component of field[1]	Max. % Difference In y-component of field[2]	Max. % Difference In Charge Density Profiles[3]
1.1906	0.127	0.03175	10	1	6	2	12	400	23
1.1906	0.127	0.03175	100	3	12	5	12	400	32
1.1906	0.127	0.0635	10	0	8	3	12	100	18
1.1906	0.127	0.0635	100	2	9	8	11	320	12
1.1906	0.127	0.127	10	3	1	8	12	53	8
1.1906	0.127	0.127	100	1	0.1	11	5	118	10
1.1906	0.127	0.15875	20	2	5	12	10	30	19
1.1906	0.127	0.15875	100	2	6	13	16	40	22
1.1906	0.200	0.0635	20	3	1	7	15	60	24
1.1906	0.200	0.0635	80	4	6	2	7	50	10
3.00	0.127	0.0635	20	2	4	2	7	50	10
3.00	0.127	0.0635	100	2	2	4	9	50	12
0.500	0.127	0.0635	10	3	9	4	15	300	14
1.016	0.1143	0.07348	20	1	3	3	9	40	9
1.016	0.1143	0.07348	200	2	1	6	10	80	15
0.1524	0.1143	0.07348	5	22	6	22	18	300	6
0.1524	0.1143	0.07348	180	9	10	9	16	213	13

---

[1] Points closer than two diameters to the wire and points near the plane connecting the centers of the wires with the plates have been neglected.

[2] Even though the percent difference in the y-components of the electric field seems quite large in some cases, the absolute error is relatively unimportant because the y-component is much smaller than the total field for nearly all such cases.

[3] Some points very near the plates and some near the centers of the wires have been neglected.

millimeters near the plate in which the space charge is distributed according to the rectangular geometry of a parallel plate arrangement. The reason for using such a small volume with rectangular symmetry is that in general the parallel plate solution predicts too large an effect due to space charge. The fact that rectangular symmetry plays such a small role in the space charge contribution to the profiles does not necessarily contradict the observations made earlier that the equipotential lines near the plate reflect a strong influence of planar geometry. The planar character of the equipotential lines is largely provided by the static-like solution which accounts rigorously for much of the charge on the plates. For cases in which the radius (R) of the cylinder of space charge is larger than the half wire-to-wire spacing, adjacent cylinders of space charge will overlap. In this situation the effects of space charge would be overestimated. To correct for that error in this simple model we reduce the contribution to the potential and electric field components from space charge associated with wires other than the central one by the fraction of the volume of the cylinder that does not extend beyond s_y. This fraction is given by

$$F = \begin{cases} 1 - \frac{2}{\pi}\left[\mathrm{ArcCos}(s_y/R) - \frac{s_y}{R^2}\,(R^2-s_y{}^2)^{\frac{1}{2}}\right], & s_y < R \\ 1 & , \; s_y \geq R\,. \end{cases} \qquad (22)$$

This factor would multiply V_1 in the space charge terms arising from wires other than the central one (m=0). Surprisingly, this simplistic correction yields rather good agreement between the approximate model and the numerically integrated solution. In all cases the approximate model agrees well with the numerically integrated solution for zero current. This case, of course, corresponds to the electrostatic solution at conditions for corona start, the limit in which the approximate model becomes exact.

Predictions of the approximate model as well as those of the numerical solution are compared with some experimental results of Penney and Matick[8] in Figures 4, 5, and 6. An effective ion mobility of 1.8×10^{-4} $m^2/V\cdot sec$ in the approximate model yields voltage-current curves which predict the experimental operating conditions to within one percent. These voltage-current curves along with the numerically integrated ones are shown in Figure 4. Figure 5 shows a comparison of the potential profiles along a line connecting the wire with the plate. The approximate model agrees with this measured potential profile to within 3 percent. A comparison of the potential profiles along a line connecting a point midway between two wires with the plate is shown in Figure 6. The approximate potential is as much as 15 percent larger than the measured potential along this line. The approximate potential is 10 percent larger than the numerically integrated

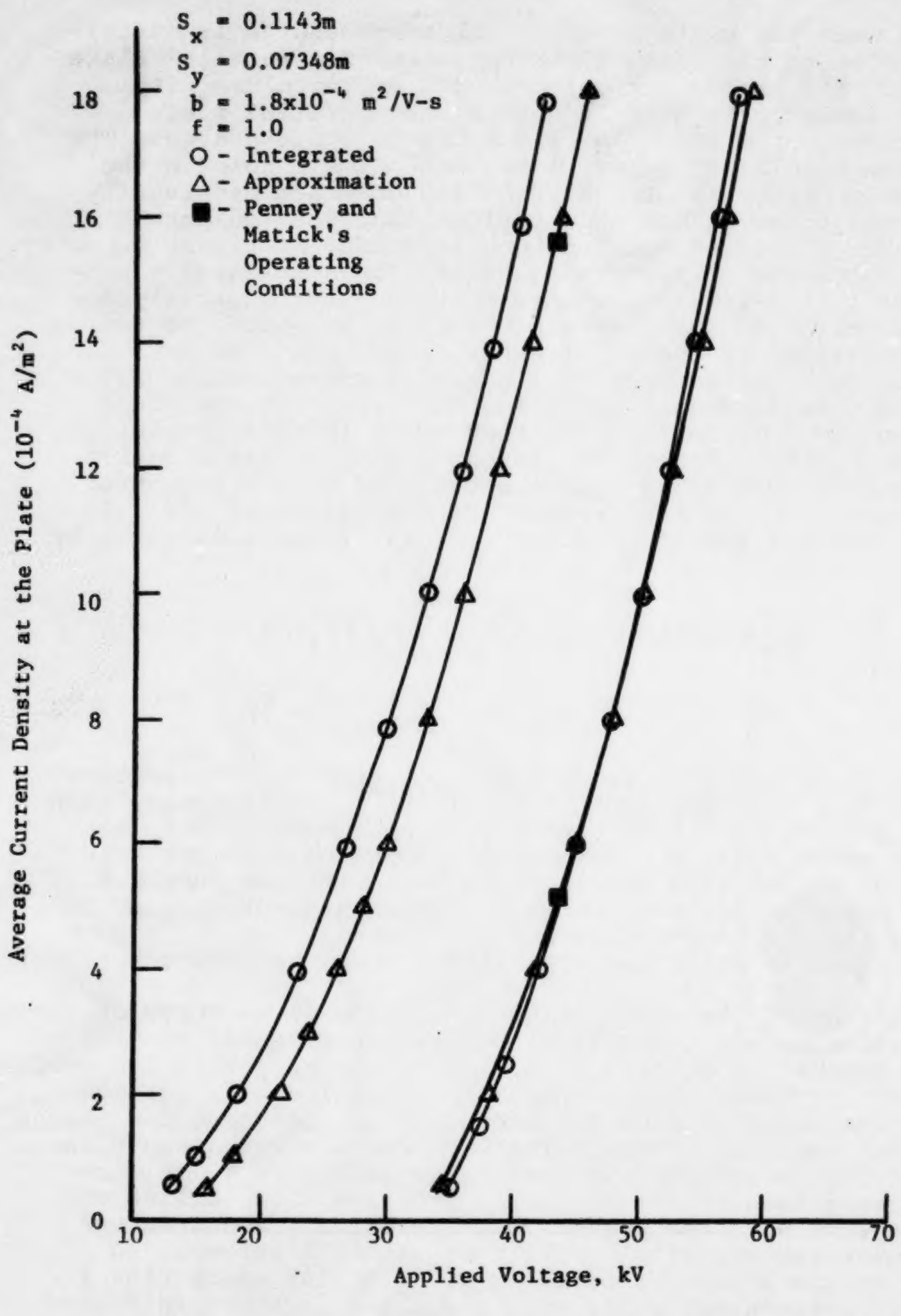

Figure 4. Current-voltage curves showing a comparison of the approximate model with the numerically integrated solution for geometrical parameters corresponding to the experimental conditions of Penney and Matick.

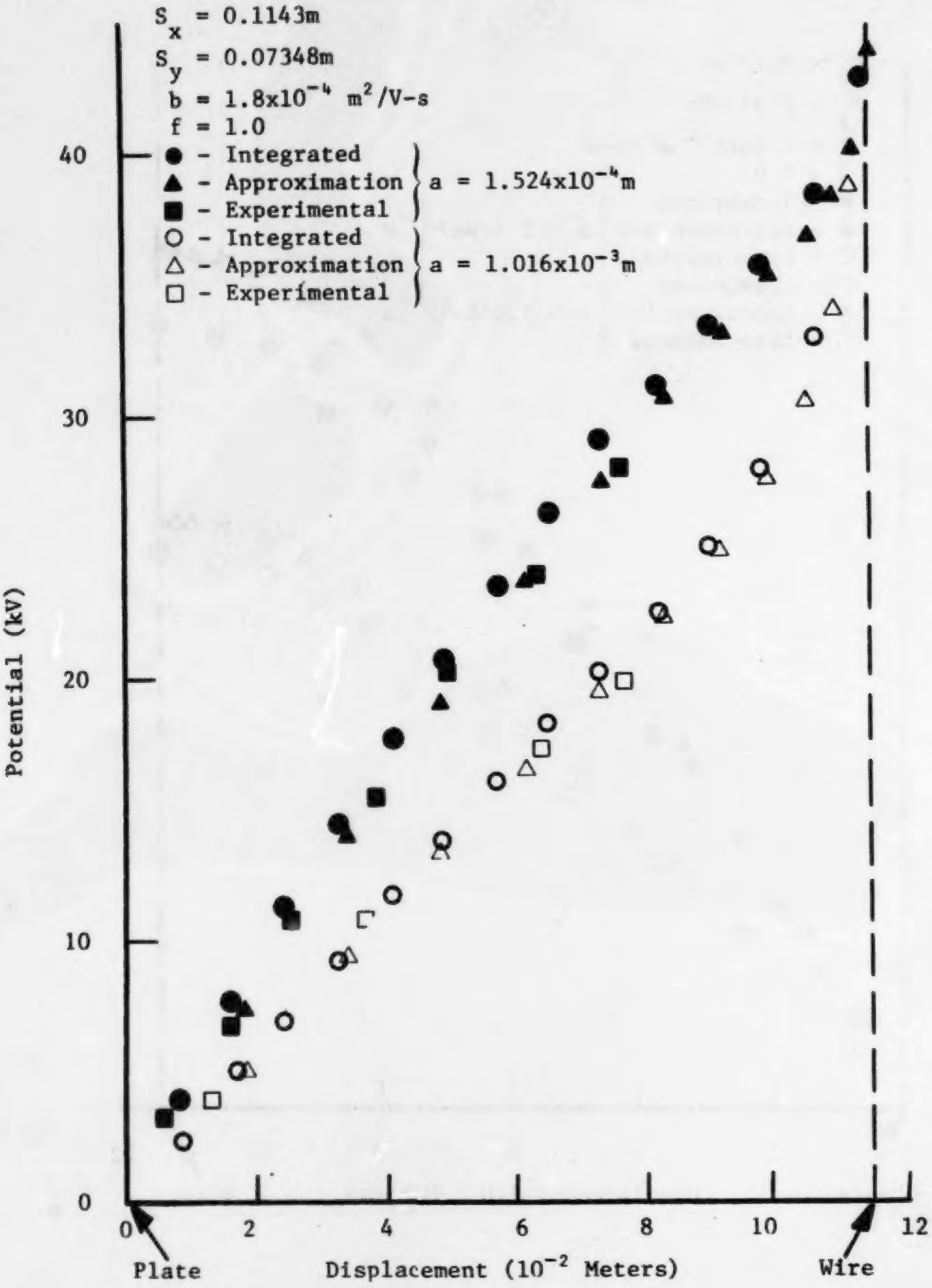

Figure 5. Comparison of theoretical potential profiles between a wire and plate with experiments of Penney and Matick.

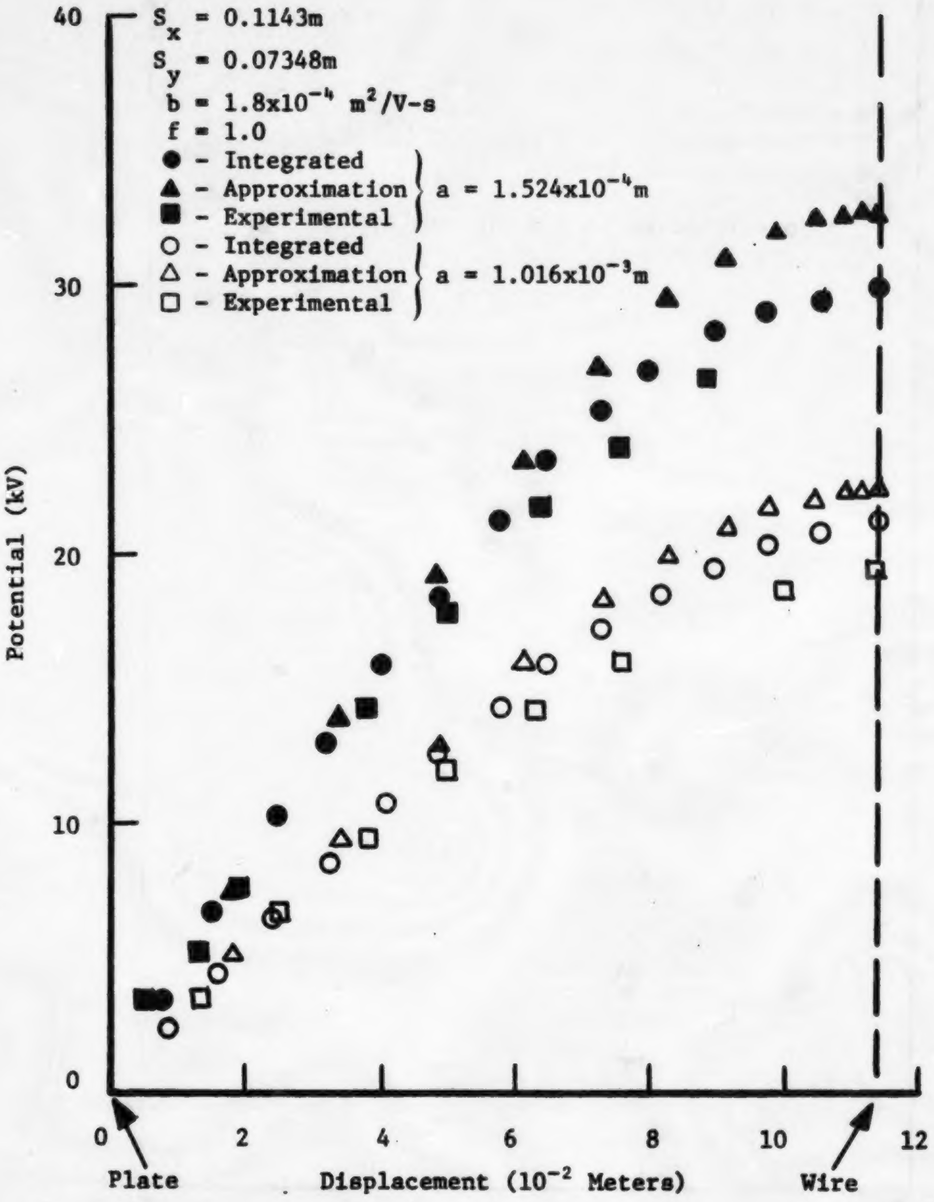

Figure 6. Comparison of theoretical potential profiles midway between wires with experiments of Penney and Matick.

potential along this same line. The apparent reason for this disagreement lies in the large current density used. A large current density corresponds to the large space charge limit where the approximation is expected to be less accurate. Also, the region between the wires is where the approximate model is expected to be least accurate. It should be noted that moderate errors in the potential profile in the regions between the wires have little influence on the predicted electrical operating conditions of the electrostatic precipitator. The value of 1.8×10^{-4} $m^2/V \cdot sec$ used for effective mobility is consistent with measured values of ion mobility in negative corona discharges in ambient air. It may be concluded that the predictions of the approximate model agree quite well both with the numerically integrated solutions and with experimentally measured electrical properties of electrostatic precipitators.

SUBROUTINE EFLD3

This subroutine calculates the electrical conditions in a wire-plate precipitator under conditions corresponding to those in both EFLD1 and EFLD2. The particular calculation to be done is determined by the value of the parameter NVII which in turn is determined by the input parameter NVI. When NVI has the value 3, NVII is set to 1 (NVI is then, also, set to 1) and a calculation analogous to the one in EFLD1 is performed. Under these conditions, either equation (9) or (12) is used to compute the average electric field at the plate. This calculation is based on known or measured values of current and voltage.

When NVI has the value 4, NVII is set to 2 (NVI is set to 2) and a calculation analogous to that in EFLD2 is performed. In this case, the subroutine calculates a voltage-current curve up to a specified value of operating voltage and calculates the average electric field at the plate for the operating applied voltage. The voltage-current curve is generated by (1) specifying a starting value of average current density at the plate, (2) incrementing upward on the average current density, and (3) determining the applied voltage at each value of current density. When a value of current density results in an applied voltage which exceeds the specified operating applied voltage, an interpolation is performed to obtain the operating voltage and current density. At this operating applied voltage, calculations can also be made to give the average current density, average electric field, and average electric field at the plate in subincremental lengths. The potential, electric field, and charge density are computed using equations (8)-(22).

The following is a sequential list of the calling arguments and their descriptions.

UEQ - Effective charge carrier mobility ($m^2/V \cdot sec$).

AC - Radius of discharge electrode (m).

VO - Chosen operating applied voltage (m).

SX - Wire-to-plate spacing (m).

SY - One-half wire-to-wire spacing (m).

NX - Number of grid points in the x-direction.

NY - Number of grid points in the y-direction.

AEPLT - Average electric field at the plate (V/m).

TDK - Temperature of the gas (°K).

P - Pressure of the gas (atm).

RF - Roughness factor for the discharge wire ($0.5 \leq RF \leq 1.0$).

START - Chosen initial current density at which the voltage-current curve calculations starts (A/m^2). Current density increments in units of START until a change is specified.

DSTART - Chosen increment in current density which is used in place of START when specified (A/m^2).

CSTART - Chosen increment in current density which is used in place of DSTART when specified (A/m^2).

IFINAL - Indicator which terminates the loop over average current densities at the plate after IFINAL times.

VSTART - Initial estimate of applied voltage corresponding to the first value of average current density at the plate on the voltage-current curve (V). VSTART is not actually used in EFLD3.

VW - Operating applied voltage corresponding to a given current density (V).

ACDNTY - Average current density at the plate (A/m^2).

NWIRE - Number of wires per gas passage per electrical section.

NEC - Indicator which governs the calculations of average current density, average electric field, and average electric field at the plate in subincremental lengths. The calculations are performed when NEC = 0 and are not performed when NEC = 1.

EBD - Electrical breakdown strength of the gas (V/m).

JI1 - Indicator which governs the change in the increment on average current density at the plate from START to DSTART. The change occurs on the JI1-th value of current density.

JI2 - Indicator which governs the change in the increment on average current density at the plate from DSTART to CSTART. The change occurs on the J12-th value of current density.

The following is a list of the variables which are in common with the main program.

EAVG(M) - Average electric field in a given subincrement of length (V/m).

CHFID(M) - Average ion density in the absence of particles in a given increment of length (#/m^3).

ECOLL(M) - Average electric field at the plate in a given subincrement of length (V/m).

VCOOP(I,J) - The static-like contribution to the potential at a grid point (V).

NPRNT - Indicator which specifies the logical unit number of the printer.

NVII - A parameter which determines whether a voltage-current curve is generated. If NVII is 1 known values of current and voltage are used. If NVII is 2 a voltage-current curve is generated.

The vollowing variables are in common with EFLD4, and CMAN.

ECX(I,J) - The x-component of the static electric field at a grid point (V/m).

ECY(I,J) - The y-component of the static electric field at a grid point (V/m).

AX(I) - The distance between the I-th and I+1-st grid points in the x-direction (m). This is used only with EFLD4.

AY(J) - The distance between the J-th and the J+1-st grid points in the y-direction (m). This is used only with EFLD4.

X1(I) - The x-position of the I-th grid point (m). This is used only with EFLD4.

Y1(J) - The y-position of the J-th grid point (m). This is used only with EFLD4.

LTEST - A logical variable which determines whether a variable or fixed grid spacing is used. When LTEST is .FALSE. a fixed spacing is used. When LTEST is .TRUE. a variable spacing is used. This variable is initialized to .FALSE. by a Block Data subprogram.

Of the above variables, the values of the following must be provided by the main program: UEQ, AC, VO, SX, SY, NX, NY, TDK, P, RF, START, DSTART, CSTART, IFINAL, VSTART, NWIRE, NEC, EBD, JI1, JI2, NVII, and NPRNT. Values of AEPLT, VW, ACDNTY, EAVG, CHFID, ECOLL, VCOOP, ECX, and ECY are determined in the subroutine. This subroutine calls subroutine CMAN to compute the static-like solutions. It also calls subroutine ARCCOS to evaluate equation (22). Since the subroutine ARCCOS has not been changed from the version described in the previous model report, it will not be described here.

There are three conditions which will terminate the calculation of the voltage-current curve in EFLD3. The calculation is terminated if (1) the specified, operating, applied voltage is reached, or (2) the number of points on the curve is equal to the value of IFINAL, or (3) the specified value of the electrical breakdown strength near the collection electrode is exceeded. If the breakdown strength is exceeded, a message to this effect is printed. Figure 7 shows a detailed flow chart of this subroutine. A listing of this subroutine is given in Appendix A.

SUBROUTINE CMAN

This subroutine calculates the static-like solution for potential and the components of electric field at each point in a grid which is established in EFLD1, EFLD2, EFLD3, or EFLD4. The calculation is based on an electrostatic solution for a wire-plate geometry. It uses equations (1), (2), (4), and (14) to compute the potential. The components of the electric field are computed from the derivatives of these equations. These expressions can be recognized in equations (12) and (13). This subroutine differs from CMAN in the previous model report primarily by the addition of the electric field component calculations.

Figure 8 shows a detailed flow chart for this subroutine. Information is transmitted between this subroutine, the main program, and other subroutines through calling arguments and common statements. The following is a sequential list of the calling arguments and their descriptions.

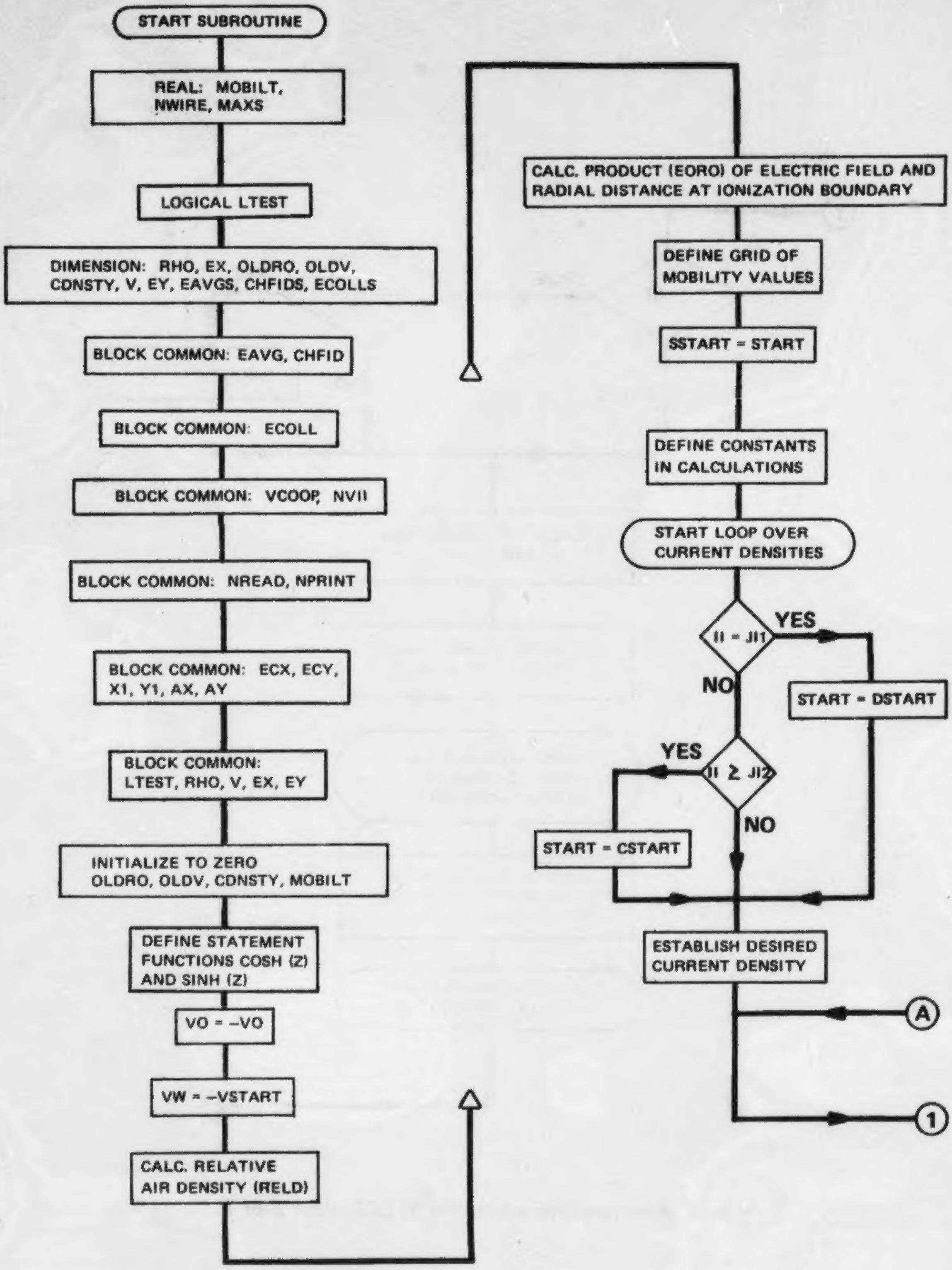
START SUBROUTINE
REAL: MOBILT, NWIRE, MAXS
LOGICAL LTEST
DIMENSION: RHO, EX, OLDRO, OLDV, CDNSTY, V, EY, EAVGS, CHFIDS, ECOLLS
BLOCK COMMON: EAVG, CHFID
BLOCK COMMON: ECOLL
BLOCK COMMON: VCOOP, NVII
BLOCK COMMON: NREAD, NPRINT
BLOCK COMMON: ECX, ECY, X1, Y1, AX, AY
BLOCK COMMON: LTEST, RHO, V, EX, EY
INITIALIZE TO ZERO OLDRO, OLDV, CDNSTY, MOBILT
DEFINE STATEMENT FUNCTIONS COSH (Z) AND SINH (Z)
VO = –VO
VW = –VSTART
CALC. RELATIVE AIR DENSITY (RELD)
CALC. PRODUCT (EORO) OF ELECTRIC FIELD AND RADIAL DISTANCE AT IONIZATION BOUNDARY
DEFINE GRID OF MOBILITY VALUES
SSTART = START
DEFINE CONSTANTS IN CALCULATIONS
START LOOP OVER CURRENT DENSITIES
II = JI1
YES
NO
START = DSTART
II ≥ JI2
YES
NO
START = CSTART
ESTABLISH DESIRED CURRENT DENSITY
A
1

Figure 7. Flow chart for subroutine EFLD3 (sheet 1 of 11).

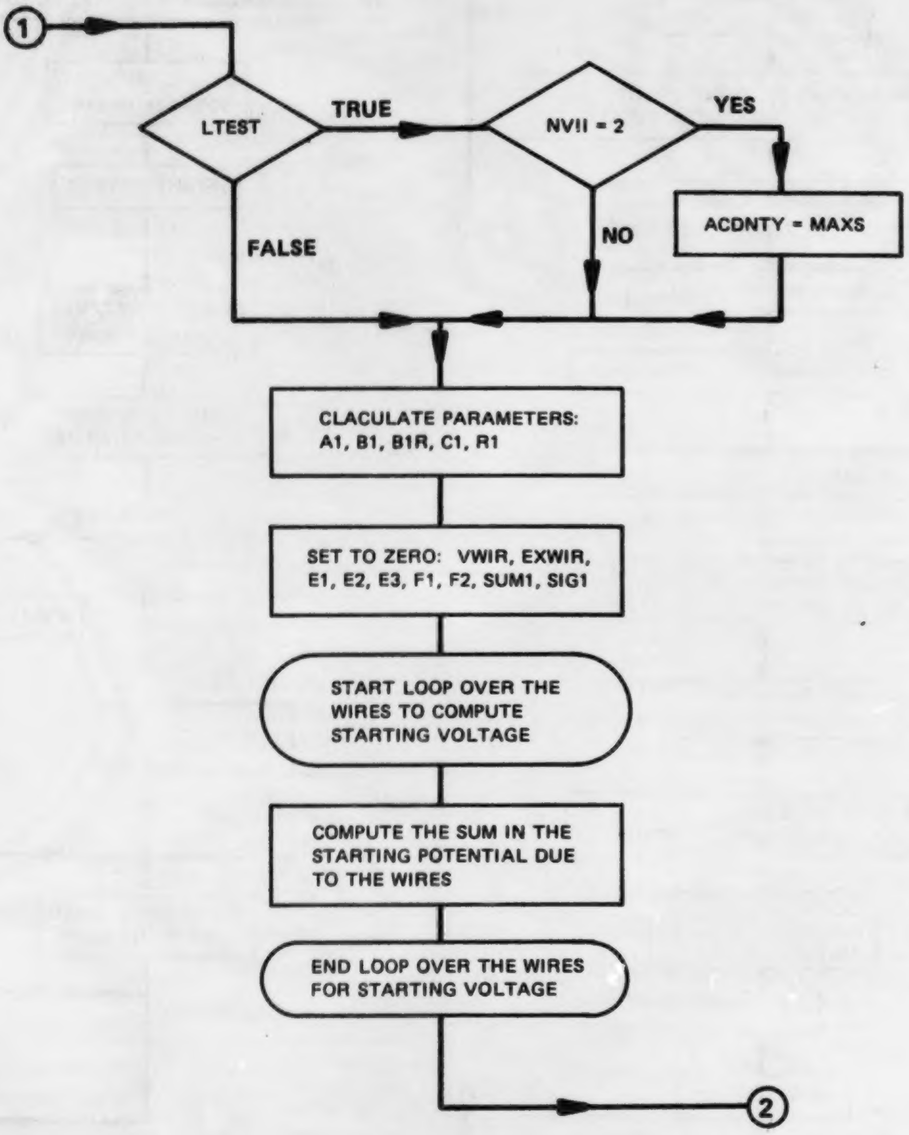
①
LTEST
TRUE
FALSE
NVII = 2
YES
NO
ACDNTY = MAXS
CLACULATE PARAMETERS: A1, B1, B1R, C1, R1
SET TO ZERO: VWIR, EXWIR, E1, E2, E3, F1, F2, SUM1, SIG1
START LOOP OVER THE WIRES TO COMPUTE STARTING VOLTAGE
COMPUTE THE SUM IN THE STARTING POTENTIAL DUE TO THE WIRES
END LOOP OVER THE WIRES FOR STARTING VOLTAGE
②

Figure 7. Flow chart for subroutine EFLD3 (sheet 2 of 11).

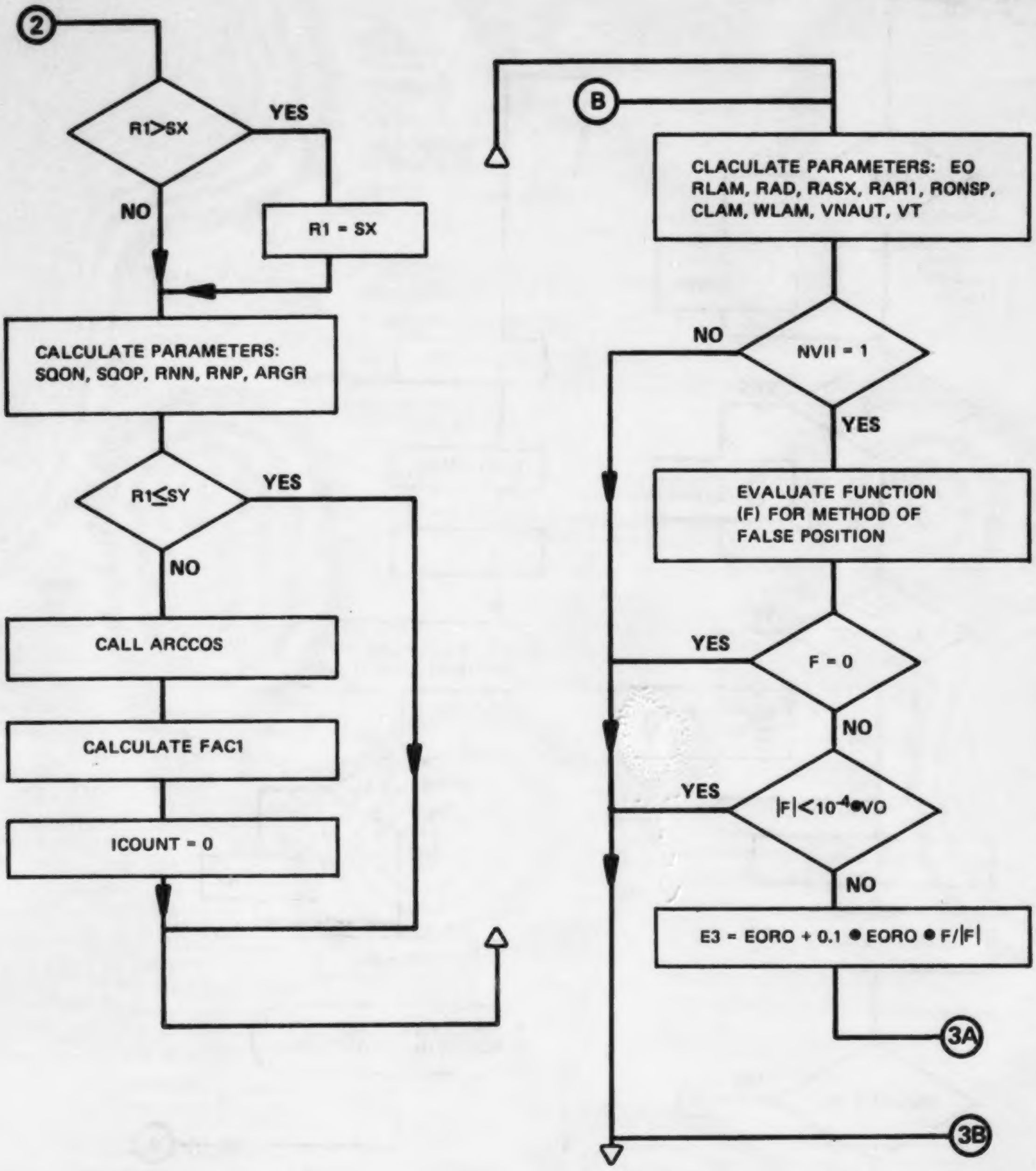
2
R1>SX
YES
NO
R1 = SX
CALCULATE PARAMETERS: SQON, SQOP, RNN, RNP, ARGR
R1≤SY
YES
NO
CALL ARCCOS
CALCULATE FAC1
ICOUNT = 0
B
CLACULATE PARAMETERS: EO RLAM, RAD, RASX, RAR1, RONSP, CLAM, WLAM, VNAUT, VT
NO
NVII = 1
YES
EVALUATE FUNCTION (F) FOR METHOD OF FALSE POSITION
YES
F = 0
NO
YES
|F|<10^-4●VO
NO
E3 = EORO + 0.1 ● EORO ● F/|F|
3A
3B

Figure 7. Flow chart for subroutine EFLD3 (sheet 3 of 11).

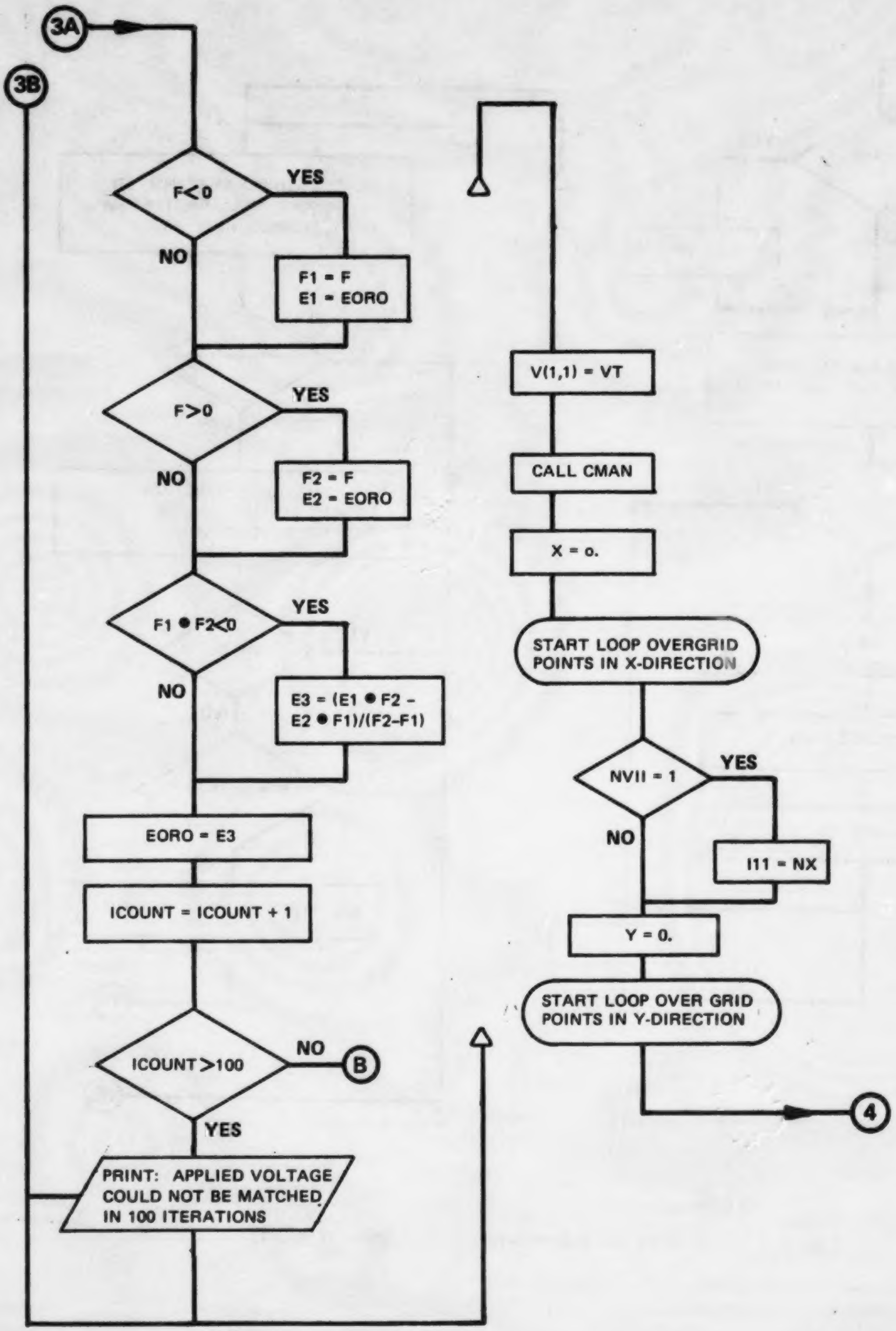

Figure 7. Flow chart for subroutine EFLD3 (sheet 4 of 11).

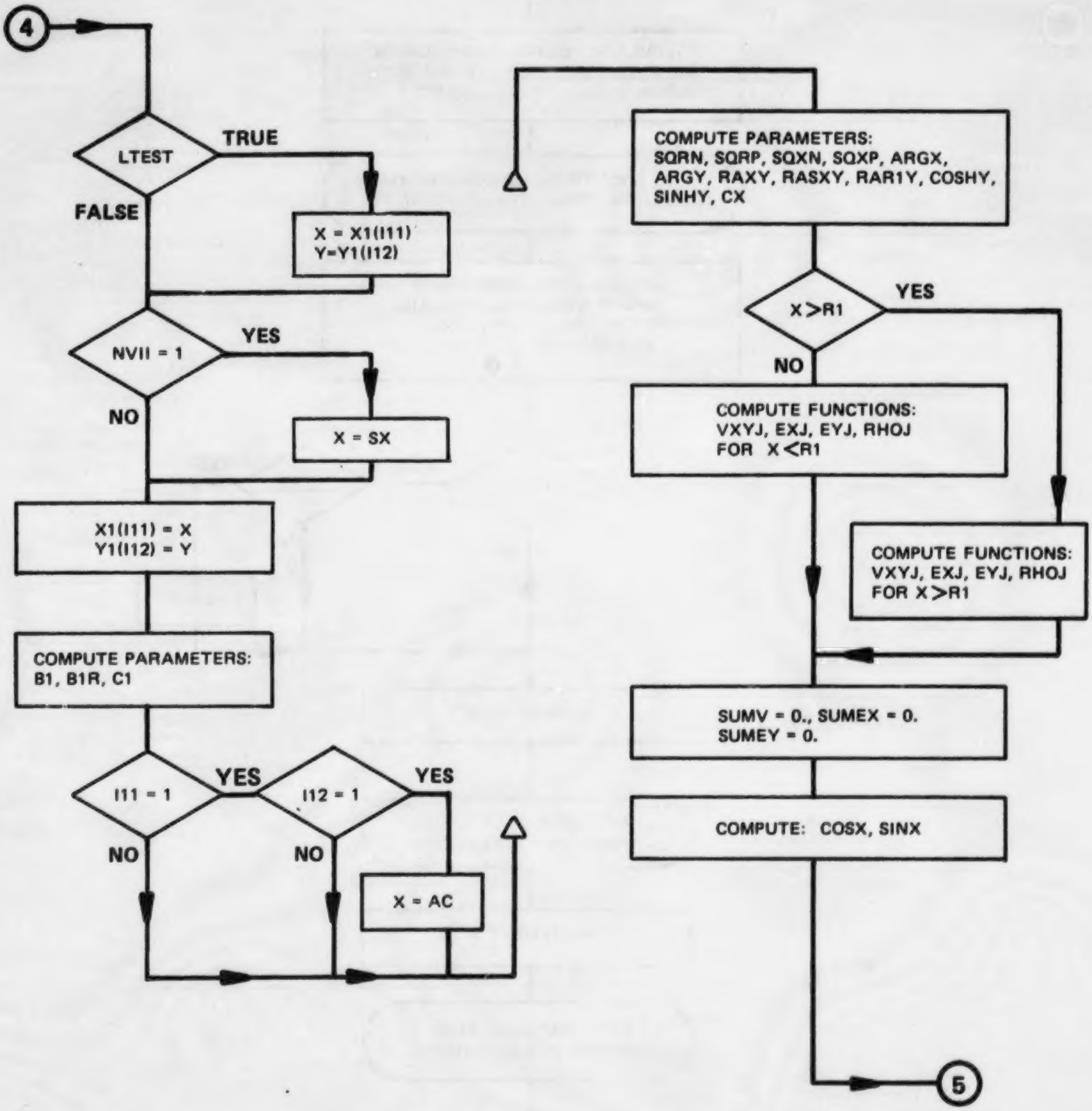

Figure 7. Flow chart for subroutine EFLD3 (sheet 5 of 11).

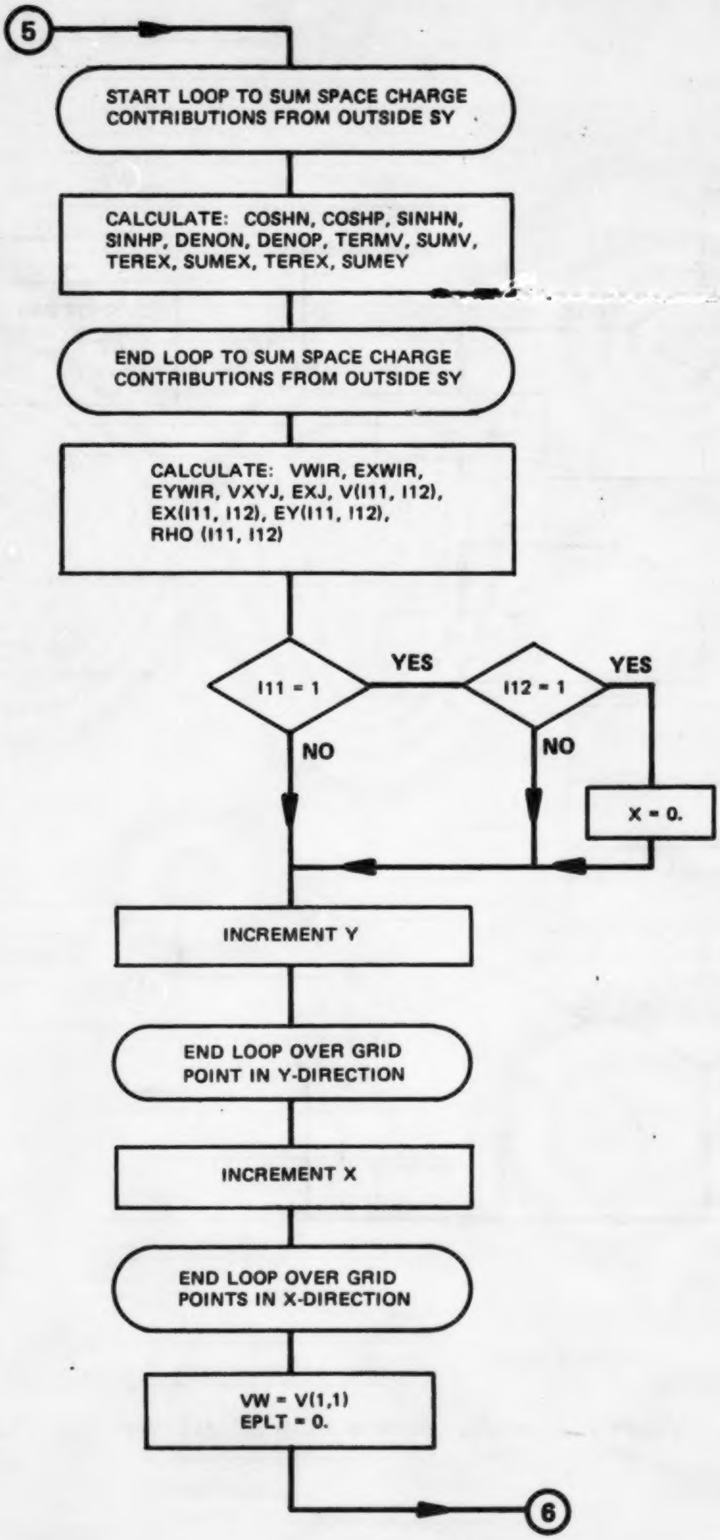
5
START LOOP TO SUM SPACE CHARGE CONTRIBUTIONS FROM OUTSIDE SY
CALCULATE: COSHN, COSHP, SINHN, SINHP, DENON, DENOP, TERMV, SUMV, TEREX, SUMEX, TEREX, SUMEY
END LOOP TO SUM SPACE CHARGE CONTRIBUTIONS FROM OUTSIDE SY
CALCULATE: VWIR, EXWIR, EYWIR, VXYJ, EXJ, V(I11, I12), EX(I11, I12), EY(I11, I12), RHO (I11, I12)
I11 = 1
YES
NO
I12 = 1
YES
NO
X = 0.
INCREMENT Y
END LOOP OVER GRID POINT IN Y-DIRECTION
INCREMENT X
END LOOP OVER GRID POINTS IN X-DIRECTION
VW = V(1,1)
EPLT = 0.
6

Figure 7. Flow chart for subroutine EFLD3 (sheet 6 of 11).

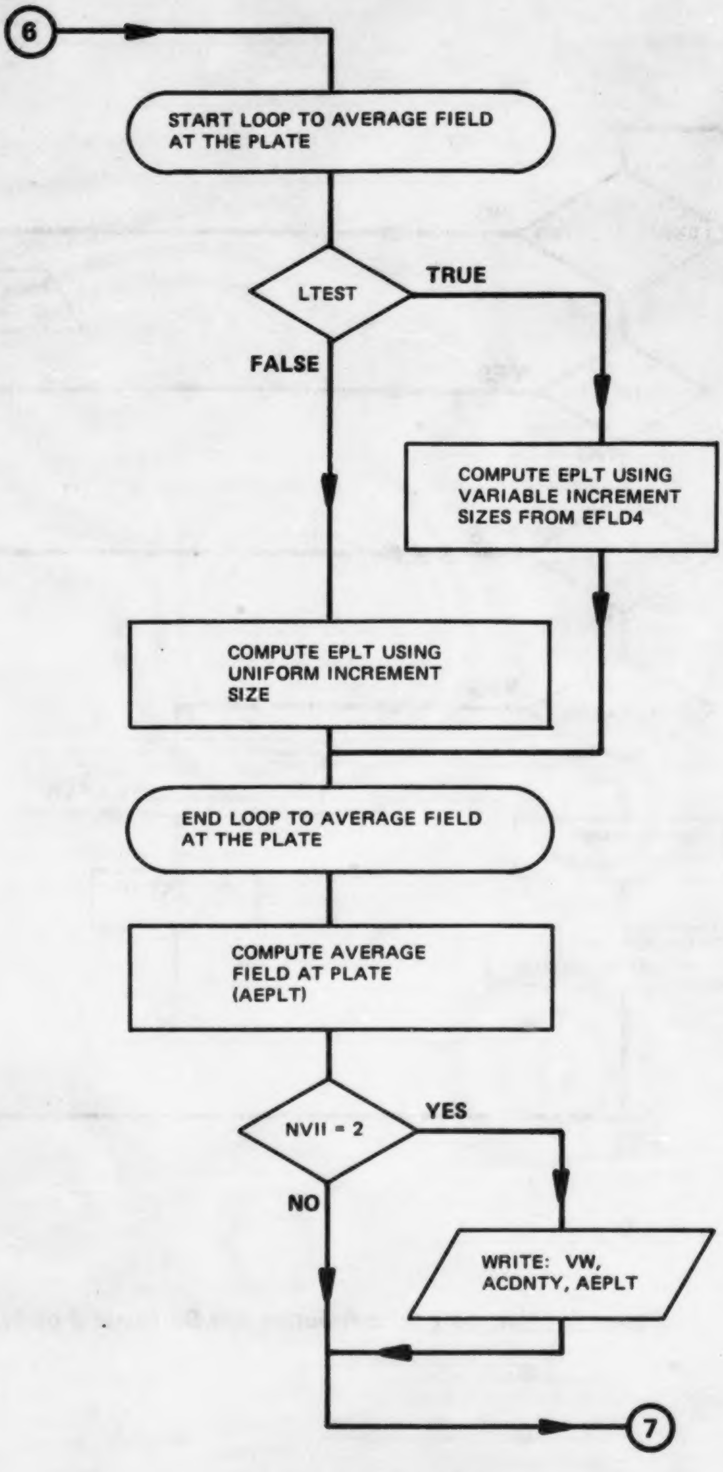
6
START LOOP TO AVERAGE FIELD AT THE PLATE
LTEST
TRUE
FALSE
COMPUTE EPLT USING VARIABLE INCREMENT SIZES FROM EFLD4
COMPUTE EPLT USING UNIFORM INCREMENT SIZE
END LOOP TO AVERAGE FIELD AT THE PLATE
COMPUTE AVERAGE FIELD AT PLATE (AEPLT)
NVII = 2
YES
NO
WRITE: VW, ACDNTY, AEPLT
7

Figure 7. Flow chart for subroutine EFLD3 (sheet 7 of 11).

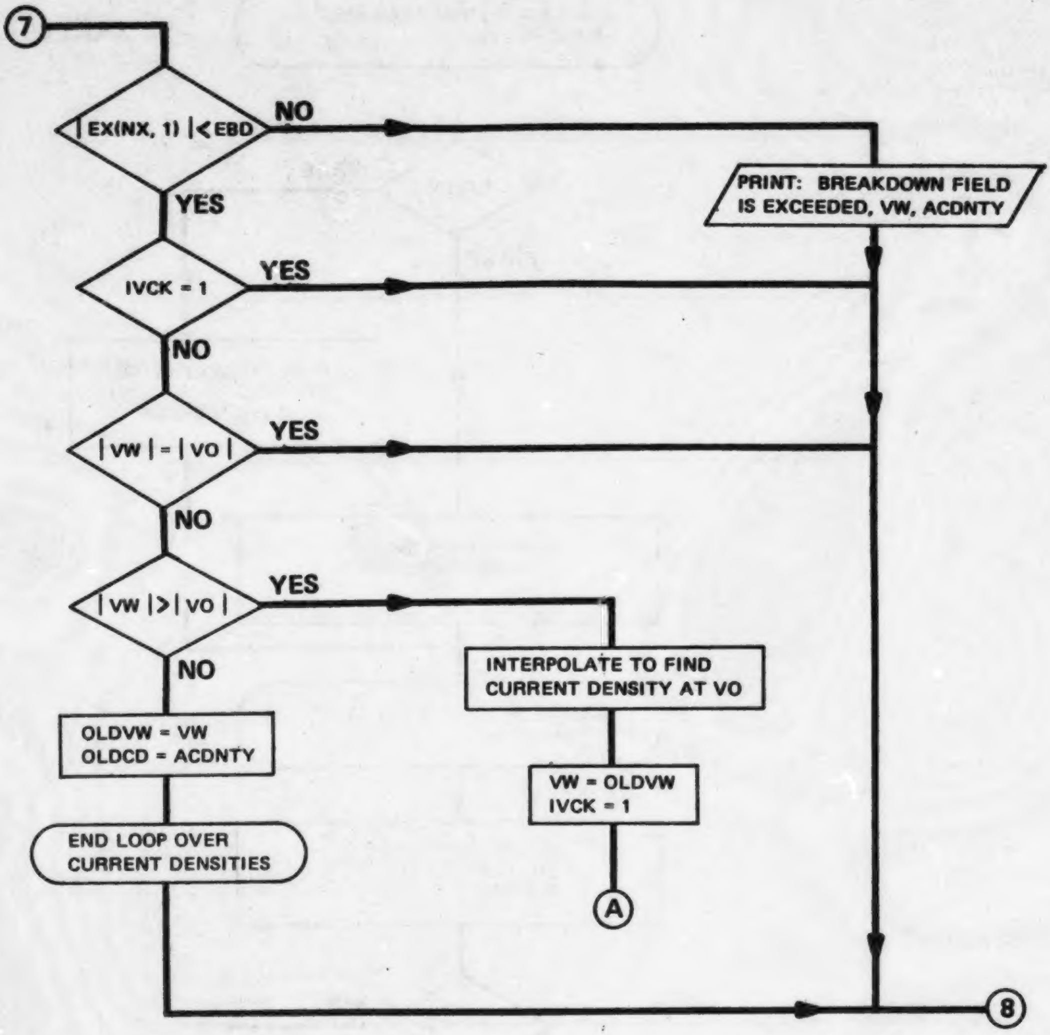

Figure 7. Flow chart for subroutine EFLD3 (sheet 8 of 11).

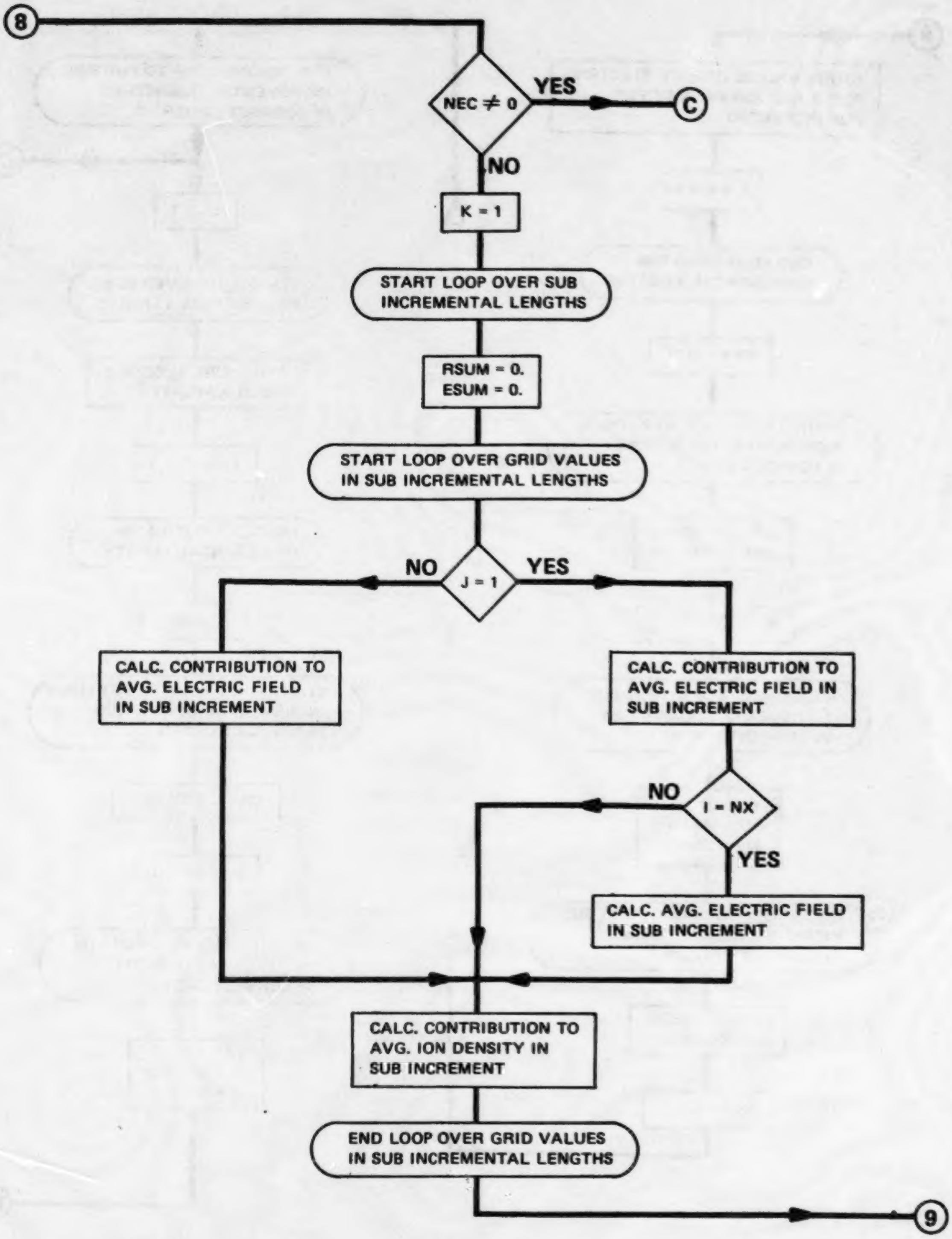
8
NEC ≠ 0
YES
C
NO
K = 1
START LOOP OVER SUB INCREMENTAL LENGTHS
RSUM = 0.
ESUM = 0.
START LOOP OVER GRID VALUES IN SUB INCREMENTAL LENGTHS
NO
J = 1
YES
CALC. CONTRIBUTION TO AVG. ELECTRIC FIELD IN SUB INCREMENT
CALC. CONTRIBUTION TO AVG. ELECTRIC FIELD IN SUB INCREMENT
NO
I = NX
YES
CALC. AVG. ELECTRIC FIELD IN SUB INCREMENT
CALC. CONTRIBUTION TO AVG. ION DENSITY IN SUB INCREMENT
END LOOP OVER GRID VALUES IN SUB INCREMENTAL LENGTHS
9

Figure 7. Flow chart for subroutine EFLD3 (sheet 9 of 11).

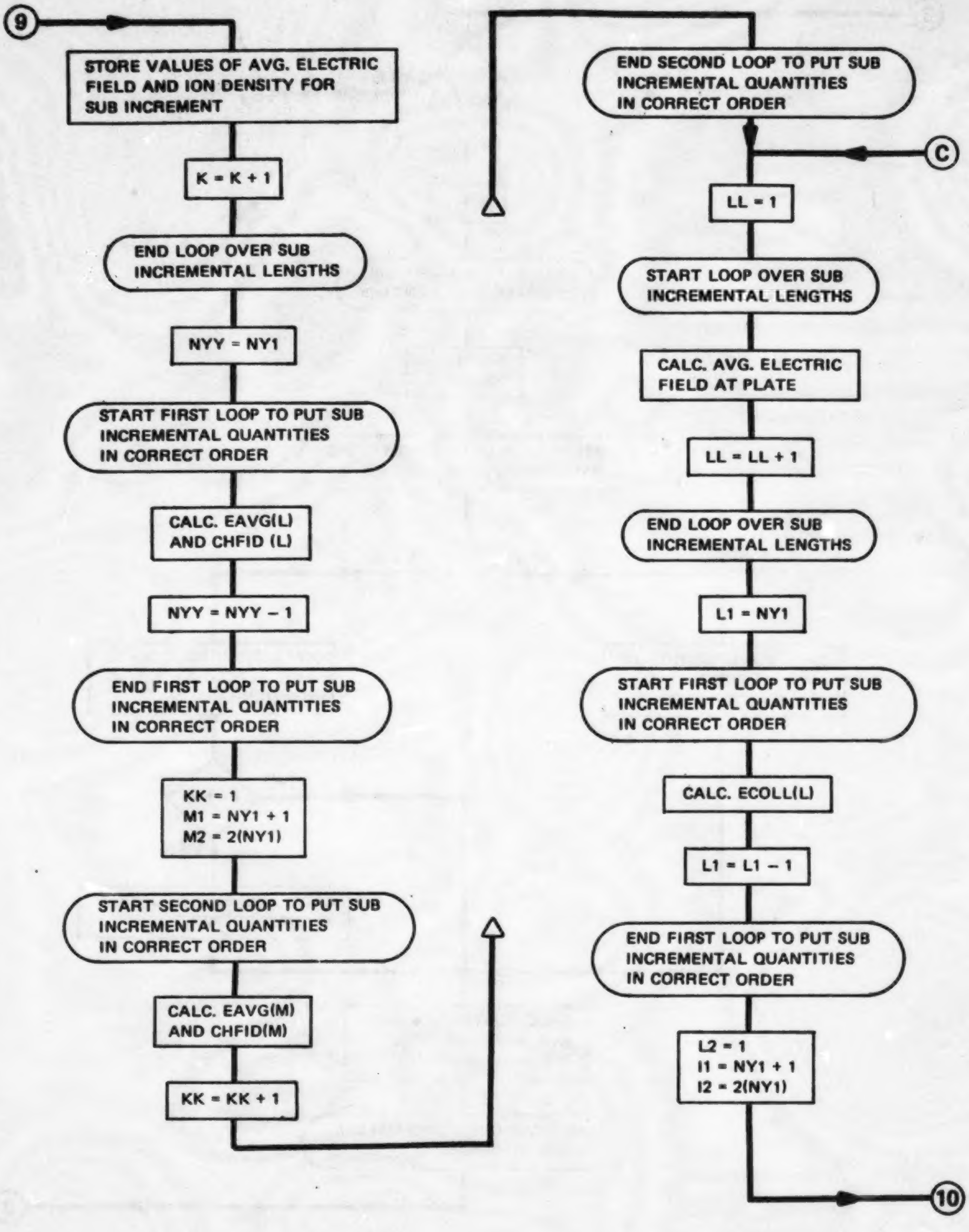
9
STORE VALUES OF AVG. ELECTRIC FIELD AND ION DENSITY FOR SUB INCREMENT
K = K + 1
END LOOP OVER SUB INCREMENTAL LENGTHS
NYY = NY1
START FIRST LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
CALC. EAVG(L) AND CHFID (L)
NYY = NYY – 1
END FIRST LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
KK = 1
M1 = NY1 + 1
M2 = 2(NY1)
START SECOND LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
CALC. EAVG(M) AND CHFID(M)
KK = KK + 1
END SECOND LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
C
LL = 1
START LOOP OVER SUB INCREMENTAL LENGTHS
CALC. AVG. ELECTRIC FIELD AT PLATE
LL = LL + 1
END LOOP OVER SUB INCREMENTAL LENGTHS
L1 = NY1
START FIRST LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
CALC. ECOLL(L)
L1 = L1 – 1
END FIRST LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
L2 = 1
I1 = NY1 + 1
I2 = 2(NY1)
10

Figure 7. Flow chart for subroutine EFLD3 (sheet 10 of 11).

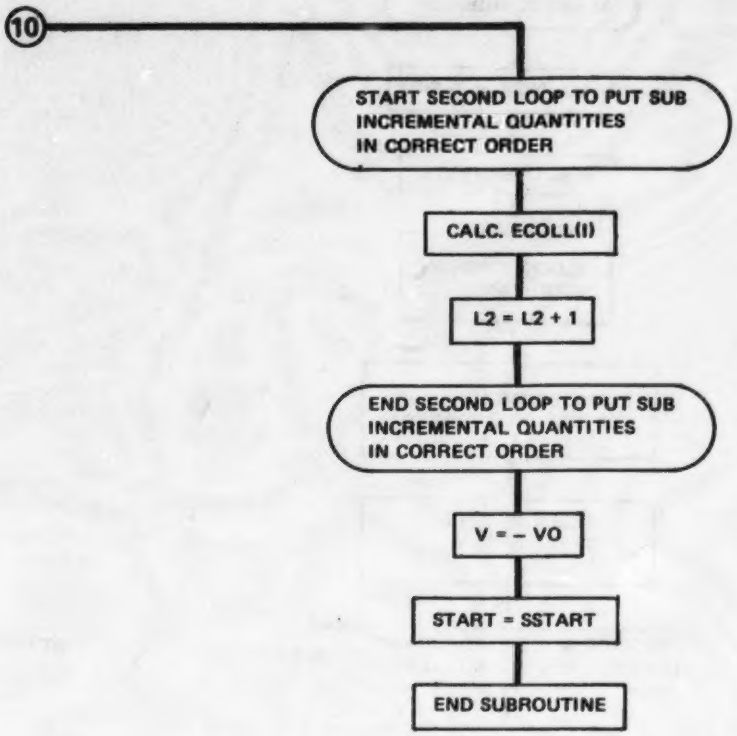
10
START SECOND LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
CALC. ECOLL(I)
L2 = L2 + 1
END SECOND LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
V = – VO
START = SSTART
END SUBROUTINE

Figure 7. Flow chart for subroutine EFLD3 (sheet 11 of 11).

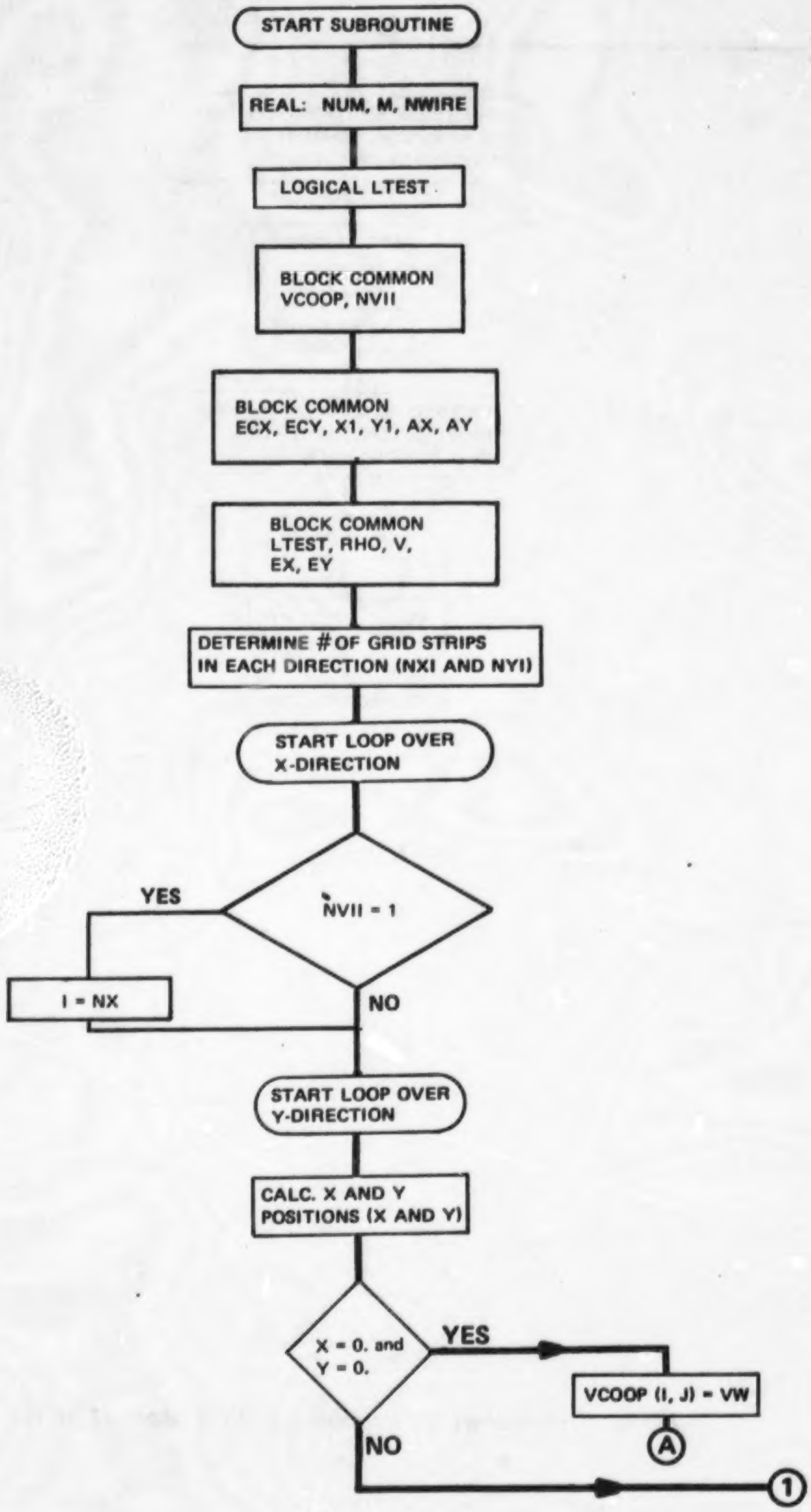
START SUBROUTINE
REAL: NUM, M, NWIRE
LOGICAL LTEST
BLOCK COMMON VCOOP, NVII
BLOCK COMMON ECX, ECY, X1, Y1, AX, AY
BLOCK COMMON LTEST, RHO, V, EX, EY
DETERMINE # OF GRID STRIPS IN EACH DIRECTION (NXI AND NYI)
START LOOP OVER X-DIRECTION
NVII = 1
YES
I = NX
NO
START LOOP OVER Y-DIRECTION
CALC. X AND Y POSITIONS (X AND Y)
X = 0. and Y = 0.
YES
VCOOP (I, J) = VW
A
NO
1

Figure 8. Flow chart for subroutine CMAN (sheet 1 of 3).

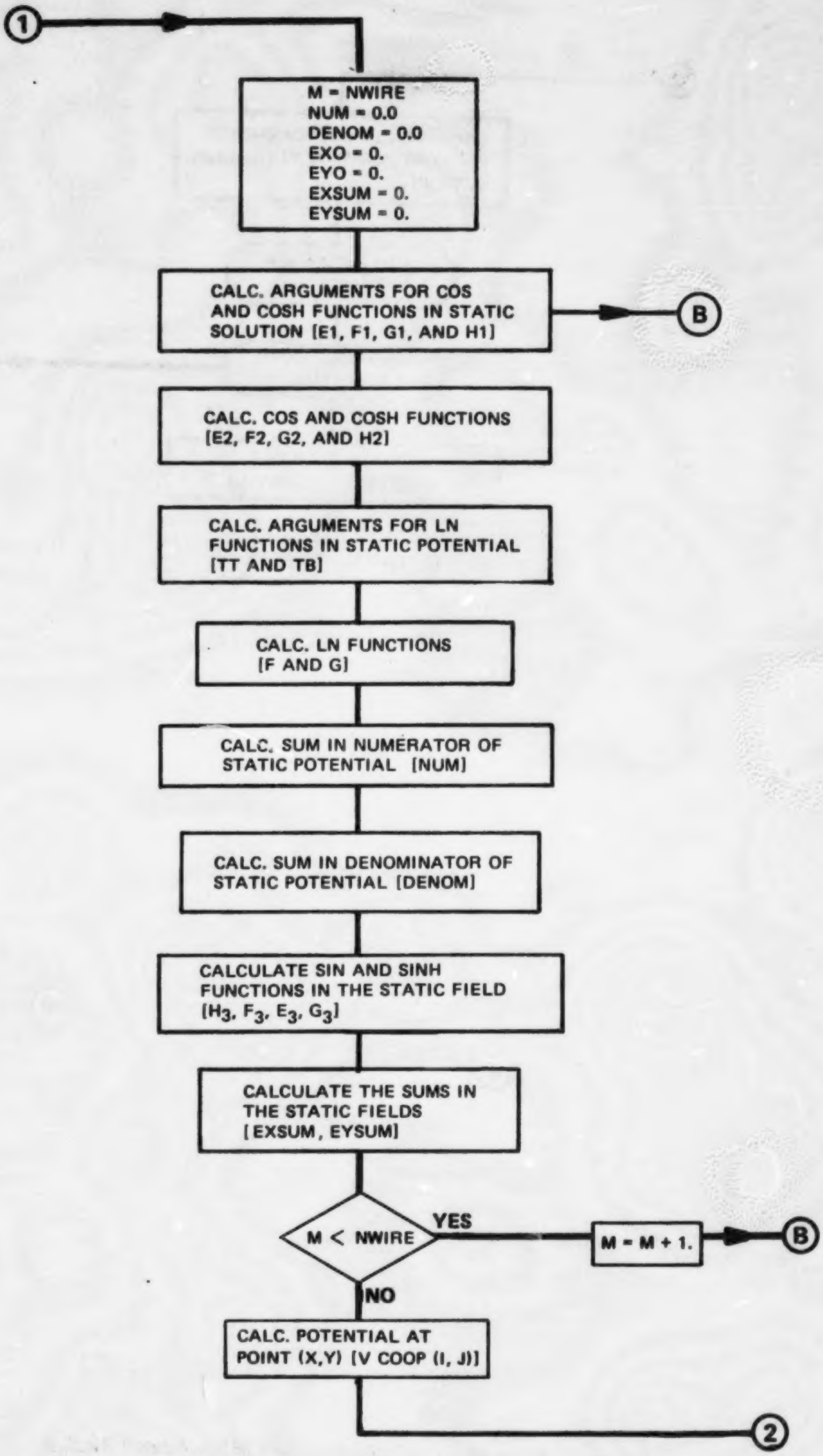
①
M = NWIRE
NUM = 0.0
DENOM = 0.0
EXO = 0.
EYO = 0.
EXSUM = 0.
EYSUM = 0.
CALC. ARGUMENTS FOR COS AND COSH FUNCTIONS IN STATIC SOLUTION [E1, F1, G1, AND H1]
B
CALC. COS AND COSH FUNCTIONS [E2, F2, G2, AND H2]
CALC. ARGUMENTS FOR LN FUNCTIONS IN STATIC POTENTIAL [TT AND TB]
CALC. LN FUNCTIONS [F AND G]
CALC. SUM IN NUMERATOR OF STATIC POTENTIAL [NUM]
CALC. SUM IN DENOMINATOR OF STATIC POTENTIAL [DENOM]
CALCULATE SIN AND SINH FUNCTIONS IN THE STATIC FIELD [H3, F3, E3, G3]
CALCULATE THE SUMS IN THE STATIC FIELDS [EXSUM, EYSUM]
M < NWIRE
YES
M = M + 1.
B
NO
CALC. POTENTIAL AT POINT (X,Y) [V COOP (I, J)]
②

Figure 8. Flow chart for subroutine CMAN (sheet 2 of 3).

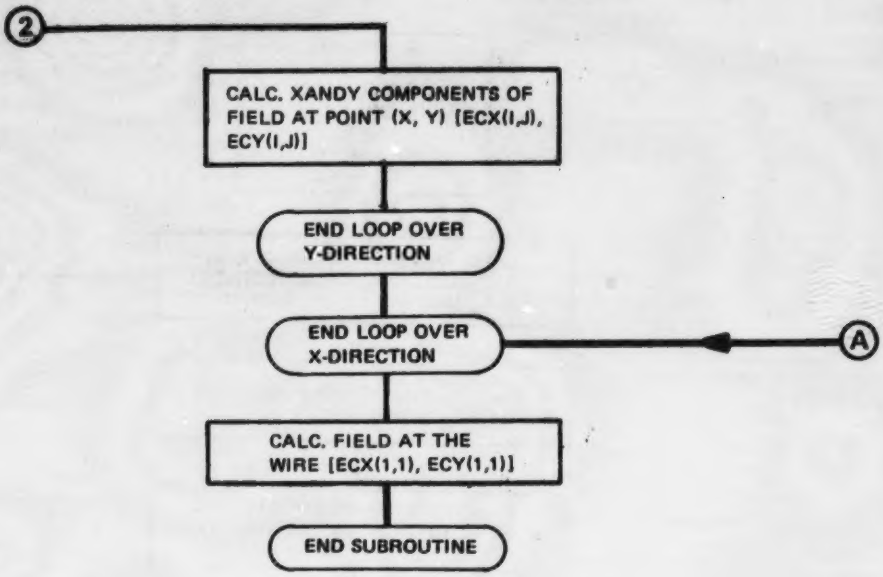
2
CALC. XANDY COMPONENTS OF FIELD AT POINT (X, Y) [ECX(I,J), ECY(I,J)]
END LOOP OVER Y-DIRECTION
END LOOP OVER X-DIRECTION
A
CALC. FIELD AT THE WIRE [ECX(1,1), ECY(1,1)]
END SUBROUTINE

Figure 8. Flow chart for subroutine CMAN (sheet 3 of 3).

VW - Electric potential at the wire (V).

NX - Number of grid points in the x-direction. It cannot exceed a value of 15.

NY - Number of grid points in the y-direction. It cannot exceed a value of 15.

SX - Wire-to-plate spacing (m).

SY - One half wire-to-wire spacing (m).

PI - Value of the constant pi.

AC - Radius of the discharge electrode (m).

NWIRE - Number of wires per gas passage per electrical section.

The following variables are in common with the main program, subroutine EFLD2, subroutine EFLD3, and subroutine EFLD4.

VCOOP(I,J) - The static potential at a point in the grid (V).

NVII - A parameter which determines whether a voltage-current curve is generated. When NVII is 1 known values of current and voltage are used. When NVII is 2 a voltage-current curve is produced.

The following variables are in common with EFLD3 and EFLD4.

ECX(I,J) - The x-component of the static electric field at a grid point (V/m).

ECY(I,J) - The y-component of the static electric field at a grid point (V/m).

AX(I) - The distance between the I-th and the I+1-st grid points in the x-direction (m). This is used only with EFLD4.

AY(J) - The distance between the J-th and the J+1-st grid points in the y-direction (m). This is used only with EFLD4.

X1(I) - The x-position of the I-th grid point (m). It is used only with EFLD4.

Y1(J) - The y-position of the J-th grid point (m). It is used only with ELFD4.

LTEST - A logical variable which distinguishes between fixed and variable grid spacing. When LTEST is TRUE the variable grid spacing of EFLD4 is used.

Of the above variables, the values of the following must be provided by the main program: VW, NX, NY, SX, SY, PI, AC, NVII, and NWIRE. Values of VCOOP, ECX, and ECY are determined in the subroutine.

SECTION 5

A GENERALIZATION OF THE INTEGRATION SCHEME USED IN THE MATHEMATICAL MODEL TO COMPUTE THE ELECTRICAL CONDITIONS IN A WIRE-DUCT PRECIPITATOR

BACKGROUND

A mathematical procedure for calculating electrical conditions in wire-duct electrostatic precipitation devices has been presented by McDonald, et al.[11] This procedure is based on a technique to numerically solve Poisson's equation and the current transport equation simultaneously under appropriate boundary conditions. Values are computed for the electric potential, electric field, and space charge density. The method of solving the transport equations is based on a numerical technique suggested by Leutert and Böhlen.[12] This technique uses equally spaced increments in approximating the derivatives by difference ratios. The use of equal increments can work well when the increments are sufficiently small. In the case of electrostatic precipitation devices, for which a typical wire-to-plate spacing is 12.7 cm (5 in.), a large number of increments are required to obtain the desired accuracy in the numerical calculation. An integration which requires a large number of increments requires both a large computer and a large amount of computing time. In addition, the use of equal increments does not allow one to account for the finite size of the corona wire unless the increments are equal to the radius of the wire. In some cases, treating the wire as if it were infinitesimally small might give rise to significant inaccuracies.

The limitations imposed on the numerical solution by using equal increments can be removed by generalizing the procedure to include variable sized increments. It has been demonstrated[13,14,15,16,17,18] that improved accuracy can be obtained with fewer integration increments if increments are adjusted to the characteristics of the particular solution. For instance, if one chooses small increments in the region where the solution varies rapidly and larger increments where the solution changes more slowly, improved overall accuracy can be obtained for a given number of integration steps. Since the wire-duct geometry represents a case in which the potential and the electric field change more rapidly near the wire than near the plate, a choice of small increments near the wire and larger increments near the plate should yield improved accuracy for a fixed number of integration steps.

DEVELOPMENT OF EQUATIONS

In the steady-state the equations which describe the electrical conditions in an electrostatic precipitator are

$$\nabla \cdot \vec{E} = \rho/\varepsilon_0 \tag{23}$$

$$\nabla \cdot \vec{J} = 0 \tag{24}$$

$$\vec{J} = \rho b \vec{E} \tag{25}$$

$$\vec{E} = -\vec{\nabla} V \tag{26}$$

where

$\vec{E}$ = electric field (V/m),

ρ = space-charge density (A sec/m^2),

ε_0 = permittivity of the gas (A sec/Vm),

J = current density (A/m^2),

V = electric potential (V),

b = mobility of charge carrier (m^2/V·sec),

x = coordinate position measured toward the plate with the corona wire as origin (m),

y = coordinate position measured parallel to the plate with the corona wire as origin (m).

In terms of potential equation (23), Poisson's equation, becomes

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = - \rho/\varepsilon_0 \quad . \tag{27}$$

Substitution of (25) and (26) into (24) yields

$$\begin{aligned} \nabla \cdot \vec{J} &= \rho b(\rho/\varepsilon_0) + b(-\nabla V) \cdot (\nabla \rho) \\ &+ \rho(-\nabla V) \cdot (\nabla b) \\ &= 0, \end{aligned} \tag{28}$$

or after rearrangement

$$\begin{aligned} (b/\varepsilon_0)\rho^2 &+ (\frac{\partial b}{\partial x} E_x + \frac{\partial b}{\partial y} E_y)\rho \\ &+ (\frac{\partial \rho}{\partial x} E_x + \frac{\partial \rho}{\partial y} E_y) b = 0 \quad . \end{aligned} \tag{29}$$

Equations (27) and (29) must be solved simultaneously for the potential and charge density. To obtain approximations for the derivatives in (27), first make a Taylor series expansion about the point labeled (2,2) in Figure 9. The potential at a point displaced by a small amount in the x-direction from point (2,2) can be written as

$$V(x,y_2) = V_{2,2} + \left.\frac{\partial V}{\partial x}\right|_{2,2} (x-x_2) + \frac{1}{2!} \left.\frac{\partial^2 V}{\partial x^2}\right|_{2,2} (x-x_2)^2 + \frac{1}{3!} \left.\frac{\partial^3 V}{\partial x^3}\right|_{2,2} (x-x_2)^3 + \ldots \qquad (30)$$

For points displaced in the y-direction, the potential would be

$$V(x_2,y) = V_{2,2} + \left.\frac{\partial V}{\partial y}\right|_{2,2} (y-y_2) + \frac{1}{2!} \left.\frac{\partial^2 V}{\partial y^2}\right|_{2,2} (y-y_2)^2 + \frac{1}{3!} \left.\frac{\partial^3 V}{\partial y^3}\right|_{2,2} (y-y_2)^3 + \ldots \quad . \qquad (31)$$

First consider the x-direction. If terms of greater than second order are neglected, the potential at adjacent grid points can be written as

$$V_{1,2} = V_{2,2} + \left.\frac{\partial V}{\partial x}\right|_{2,2} (-ax_1) + \frac{1}{2} \left.\frac{\partial^2 V}{\partial x^2}\right|_{2,2} (-ax_1)^2 \qquad (32)$$

and

$$V_{3,2} = V_{2,2} + \left.\frac{\partial V}{\partial x}\right|_{2,2} (ax_2) + \frac{1}{2} \left.\frac{\partial^2 V}{\partial x^2}\right|_{2,2} (ax_2)^2 \quad , \qquad (33)$$

where

$$ax_1 = x_2 - x_1$$
$$ax_2 = x_3 - x_2 \quad . \qquad (34)$$

To eliminate the first derivative, multiply (32) by ax_2/ax_1, and add the result to (33). After some rearrangement, the second derivative becomes

$$\left.\frac{\partial^2 V}{\partial x^2}\right|_{2,2} = \frac{2[ax_1 V_{3,2} + ax_2 V_{1,2} - V_{2,2}(ax_1 + ax_2)]}{ax_1 ax_2 (ax_1 + ax_2)} \quad . \qquad (35)$$

Similar considerations for the y-direction yield

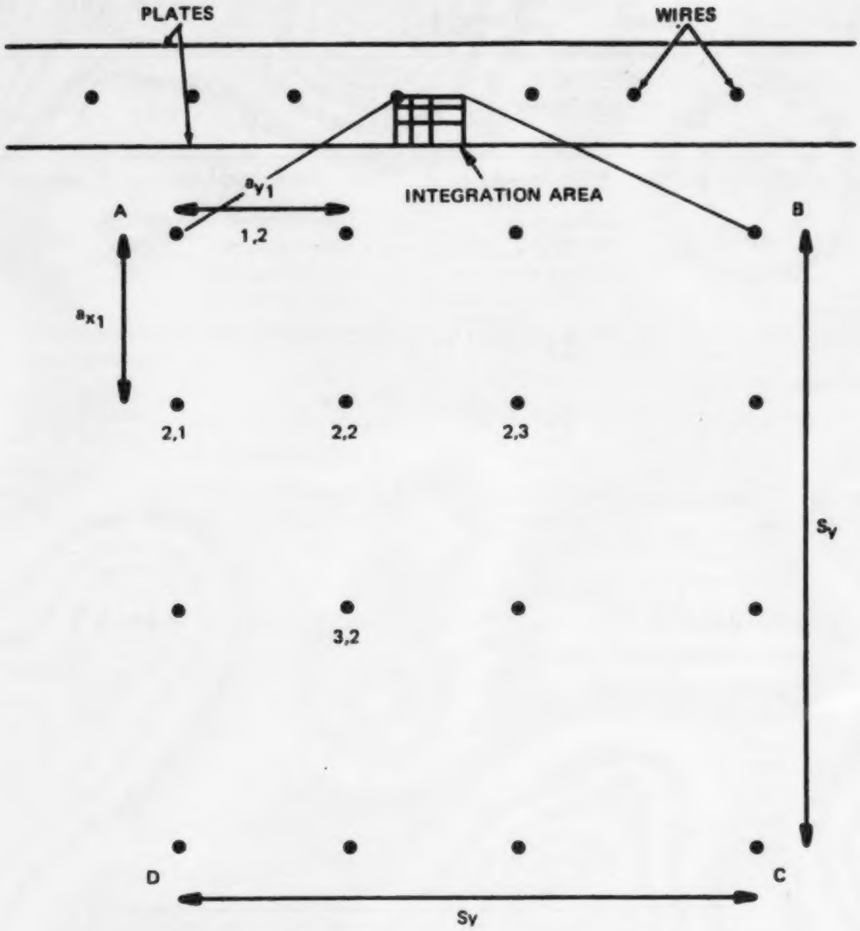

Figure 9. Schematic illustrating positions of integration grid points in the new integration scheme.

$$\left.\frac{\partial^2 V}{\partial y^2}\right|_{2,2} = \frac{2[ay_1 V_{2,3} + ay_2 V_{2,1} - V_{2,2}(ay_1 + ay_2)]}{ay_1 ay_2 (ay_1 + ay_2)} \quad . \qquad (36)$$

Equations (35) and (36) can be used in Poisson's equation to compute

$$V_{2,2} = \left(\frac{ax_1 ax_2 ay_1 ay_2}{ax_1 ax_2 + ay_1 ay_2}\right)\left[\frac{ax_1\ V_{3,2} + ax_2\ V_{1,2}}{ax_1 ax_2\ (ax_1 + ax_2)} + \frac{ay_1\ V_{2,3} + ay_2\ V_{2,1}}{ay_1 ay_2\ (ay_1 + ay_2)} + \frac{\rho_{2,2}}{2\varepsilon_0}\right] \quad . \qquad (37)$$

The components of the electric field can be obtained from the partial derivatives of the potential. If the second derivatives are eliminated from (32) and (33), one obtains

$$E_x = -\left.\frac{\partial V}{\partial x}\right|_{2,2} = -\frac{ax_1^2\ V_{3,2} - ax_2^2\ V_{1,2} - V_{2,2}\ (ax_1^2 - ax_2^2)}{ax_1 ax_2 (ax_1 + ax_2)} \qquad (38)$$

and

$$E_y = -\left.\frac{\partial V}{\partial y}\right|_{2,2} = -\frac{ay_1^2\ V_{2,3} - ay_2^2\ V_{2,1} - V_{2,2}\ (ay_1^2 - ay_2^2)}{ay_1 ay_2 (ay_1 + ay_2)} \quad . \qquad (39)$$

While equation (37) generalizes the potential calculation to allow for an arbitrary choice of grid spacings, equations (38) and (39) should yield more accurate values of the field components since these equations depend on the potential at three points instead of only two.

The electric field and potential are computed at the boundaries of the integration cells, while the charge density is associated with the centers of the cells. To be consistent with these assumptions, and avoid using two interlacing grids of computational points, we use a different discretization scheme for the charge density and carrier mobility. The derivatives of these two functions are approximated by difference ratios based on the spacing of the cell boundaries.

$$\left.\frac{\partial \rho}{\partial x}\right|_{2,2} = \frac{\rho_{2,2} - \rho_{1,2}}{ax_1}$$

$$\left.\frac{\partial \rho}{\partial y}\right|_{2,2} = \frac{\rho_{2,2} - \rho_{2,1}}{ay_1}$$

$$\left.\frac{\partial b}{\partial x}\right|_{2,2} = \frac{b_{2,2} - b_{1,2}}{ax_1}$$

$$\left.\frac{\partial b}{\partial y}\right|_{2,2} = \frac{b_{2,2} - b_{2,1}}{ay_1} \quad . \tag{40}$$

The charge density can then be interpreted as the average value within the cell. Since the charge density varies more slowly than the field and potential, the accuracy of the discretization equation is not critical. Substitution of (40) into (29) leads to

$$\rho_{2,2} = -\alpha \pm (\alpha^2 - \beta)^{\frac{1}{2}} \quad , \tag{41}$$

where

$$\alpha = \frac{\varepsilon_0}{2b_{2,2}} \left[E_x \left(\frac{2b_{2,2} - b_{1,2}}{ax_1}\right) + E_y \left(\frac{2b_{2,2} - b_{2,1}}{ay_1}\right)\right] \tag{42}$$

and

$$\beta = -\varepsilon_0 \left[\frac{E_x \, \rho_{1,2}}{ax_1} + \frac{E_y \, \rho_{2,1}}{ay_1}\right] \quad . \tag{43}$$

Both E_x and E_y are evaluated at point (2,2). In effect, the charge density is based on a two point approximation. These equations have the advantage that the charge density in a cell can be updated immediately using the new value of the field at the cell boundary. This iterative scheme has the advantage over the old scheme that new values of all the functions (potential, field, and charge density) are computed each time through the grid of points. In the old scheme, two sweeps through the grid points were required to update all the functions. As implied above, equations (37), (38), (39), and (41) can be solved simultaneously for the potential, field and charge density at point (2,2). Point (2,2) will then be moved successively to all points in the grid producing values of potential, field and charge density at each point.

BOUNDARY CONDITIONS

The solutions for the potential, electric field and charge density must be obtained subject to a certain set of boundary conditions. The current set of boundary conditions is given by

(1) $\rho = \rho_s$, the charge density at the surface of the corona,

(2) $E_x = 0$ along aline AB of Figure 9,

(3) $E_y = 0$ along lines BC, CD, and AD in Figure 9,

(4) $\rho = J/E_x b$ near the plate.

SUBROUTINE EFLD4

This subroutine calculates a voltage-current curve up to a specified value of operating voltage and calculates the average electric field at the plate for the operating applied voltage. The voltage-current curve is generaged by (1) specifying a starting value of average current density at the plate, (2) incrementing upward on the average current density, and (3) determining the applied voltage at each value of current density. When a value of current density results in an applied voltage which exceeds the specified operating applied voltage, an interpolation is performed to obtain the operating voltage and current density. At this operating applied voltage, calculations can also be made to give the average current density, average electric field, and average electric field at the plate in subincremental lengths. As pointed out earlier, this subroutine was used for the comparisons with the approximate solutions shown in Table 1.

The potential, electric field, and charge density are computed by solving equations (37), (38), (39), and (41) simultaneously using a relaxation technique. In solving the equations, the corona region near the wire is treated as a source of ions. It is assumed that the change in potential across the corona region can be described by

$$\Delta V = VW - V(2,1) = ECOR\ (RC - AC), \qquad (44)$$

where

VW = potential at the surface of the wire (V),

V(2,1) = V(1,2) = potential at the surface of the corona (V),

ECOR = average field required to drive the corona (V/m),

RC = radius of corona (m),

AC = radius of the wire.

Note that the potential drop across the corona region will be small when the two radii are nearly equal. The case in which RC = AC corresponds to the conditions used in the model previously. It is assumed that the corona is cylindrical.

Numerical Algorithm

(1) Calculate the potential, electric fields, and charge density at the grid points using the approximate solution presented earlier.

(2) Hold the potential at the wire fixed, recalculate the potential, the fields, and the charge density at the grid points using equations (37), (38), (39), and (41) - (43).

(3) Repeat step 2 iteratively until the potential profile changes negligibly in successive interations.

(4) Check to see if the average current density at the plate is the desired value. If the average current density agrees with the specified value, a solution has been obtained. If the average current density at the plate does not agree with the specified value, adjust the potential at the wire and repeat steps 3 and 4.

The primary differences between this subroutine and EFLD2 of the mathematical model are:

(1) EFLD4 uses variable sized integration increments.

(2) EFLD4 can account for the potential drop across the corona.

(3) EFLD4 accounts for the finite size of the corona region by specifying the potential there.

(4) EFLD4 computes the average current density at the plate by integrating over the plate rather than computing the mean value from several points.

(5) EFLD4 also computes the average field at the plate by integrating over the plate.

(6) EFLD4 calls EFLD3 to obtain an approximate starting solution.

(7) EFLD4 uses the method of false position to obtain the correct current density.

(8) EFLD4 does not require a value of VSTART.

(9) EFLD4 uses more stringent conditions for convergence of potential and current density than does EFLD2.

The following is a sequential list of the calling arguments and their descriptions.

UEQ - Effective charge carrier mobility ($m^2/V \cdot sec$).

AC - Radius of discharge electrode (m).

VO - Chosen operating applied voltage (m).

SX - Wire-to-plate spacing (m).

SY - One-half wire-to-wire spacing (m).

NX - Number of grid points in x-direction.

NY - Number of grid points in y-direction.

AEPLT - Average electric field at the plate (V/m).

TDK - Temperature of the gas (°K).

P - Pressure of the gas (atm).

RF - Roughness factor for the discharge wire ($0.5 \le RF \le 1.0$).

START - Chosen initial current density at which the voltage current curve calculation starts (A/m^2). Current density increments in units of START until a change is specified.

DSTART - Chosen increment in current density which is used in place of START when specified (A/m^2).

CSTART - Chosen increment in current density which is used in place of DSTART when specified (A/m^2).

IFINAL - Indicator which terminates the loop over average current densities at the plate after IFINAL times.

VSTART - Initial estimate of applied voltage corresponding to the first value of average current density at the plate on the voltage-current curve (V). VSTART is not actually used in EFLD4 to start the integration.

VW - Operating applied voltage corresponding to a given current density (V).

ACDNTY - Average current density at the plate (A/m^2).

NWIRE - Number of wires per gas passage per electrical section.

NEC - Indicator which governs the calculations of average current density, average electric field, and average electric field at the plate in subincremental lengths. The calculations are performed when NEC = 0 and are not performed when NEC = 1.

EBD - Electrical breakdown strength of the gas (V/m).

JI1 - Indicator which governs the change in the increment on average current density at the plate from START to DSTART. The change occurs on the JI1-th value of current density.

JI2 - Indicator which governs the change in the increment on average current density at the plate from DSTART to CSTART. The change occurs on the JI2-th value of current density.

The following is a list of the variables which are in common with the main program.

EAVG(M) - Average electric field in a given subincrement of length (V/m).

CHFID(M) - Average ion density in the absence of particles in a given subincrement of length ($\#/m^3$).

ECOLL(M) - Average electric field at the plate in a given subincrement of length (V/m).

NPRNT - Indicator which specifies the logical unit number of the printer.

The following is a list of variables which are in common with subroutines EFLD3 and CMAN.

ECX(I,J) - The x-component of the static electric field at a grid point (V/m).

ECY(I,J) - The y-component of the static electric field at a grid point (V/m).

AX(I) - The distance between the I-th and the I+1-st grid points in the x-direction (m).

AY(J) - The distance between the J-th and the J+1-st grid points in the y-direction (m).

X1(I) - The length of the I-th increment in the x-direction (m). This is used only with EFLD4.

Y1(J) - The length of the J-th increment in the y-direction (m). This is used only with EFLD4.

LTEST - A logical variable which distinguishes between fixed and variable grid spacings. When LTEST is TRUE the variable grid spacing of EFLD4 is used.

VCOOP - The static-like contribution to the potential (V).

NVII - A parameter which determines whether a voltage-current curve is generated.

Of the above variables, the values of the following must be provided by the main program: UEQ, AC, VO, SX, SY, NX, NY, TDK, P, RF, START, DSTART, CSTART, IFINAL, VSTART, NWIRE, NEC, EBD, JI1, JI2, NVII, and NPRNT. Values of AEPLT, VW, ACDNTY, EAVG, CHFID, ECOLL, VCOOP, ECX, ECY, X1, Y1, AX, AY, and LTEST are determined in the subroutine. The subroutine calls subroutine EFLD3 to obtain initial approximations for the potential, electric field, and charge density at the grid points.

If, for a given current density, convergence on the potential grid can not be obtained in 4000 iterations, a message stating that convergence can not be obtained is printed and those values which were calculated in the last iteration are used for that particular point on the voltage-current curve. If convergence on a given average current density at the plate can not be obtained in 25 iterations, a message stating that convergence can not be obtained is printed and those values which were calculated in the last iteration are used for that particular point on the voltage-current curve.

There are three conditions which will terminate the calculation of the voltage-current curve. The calculation is terminated if (1) the specified operating applied voltage is reached, or (2) the number of points on the curve is equal to the value of IFINAL, or (3) the specified value of the electrical breakdown strength near the collection electrode is exceeded. If the breakdown strength is exceeded, a message to this effect is printed. Figure 10 shows a detailed flow chart of this subroutine. A listing of this subroutine is given in Appendix C.

This subroutine calls subroutine EFLD3 which was described earlier. The arrays containing the variable grid spacings are transmitted through a common statement. The logical variable LTEST is used to distinguish the variable spacing of EFLD4 from the fixed spacings used in the previous model. The variable, LTEST, is initialized to FALSE in both CMAN and EFLD3 by a data block subprogram.

SUBROUTINE OUTPUT

This subroutine prints the arrays computed in EFLD4. It prints all rows corresponding to the NX grid points in the x-direction. If NY is greater than 18, only selected columns corresponding to certain values of Y are printed. The first 9 columns are printed, then 9 columns chosen by a multiple which spans the remaining columns are printed. The values of Y are printed above the columns, and the values of X are printed beside the rows. For each point in the array which is printed, the potential is printed under the charge density, the x-component

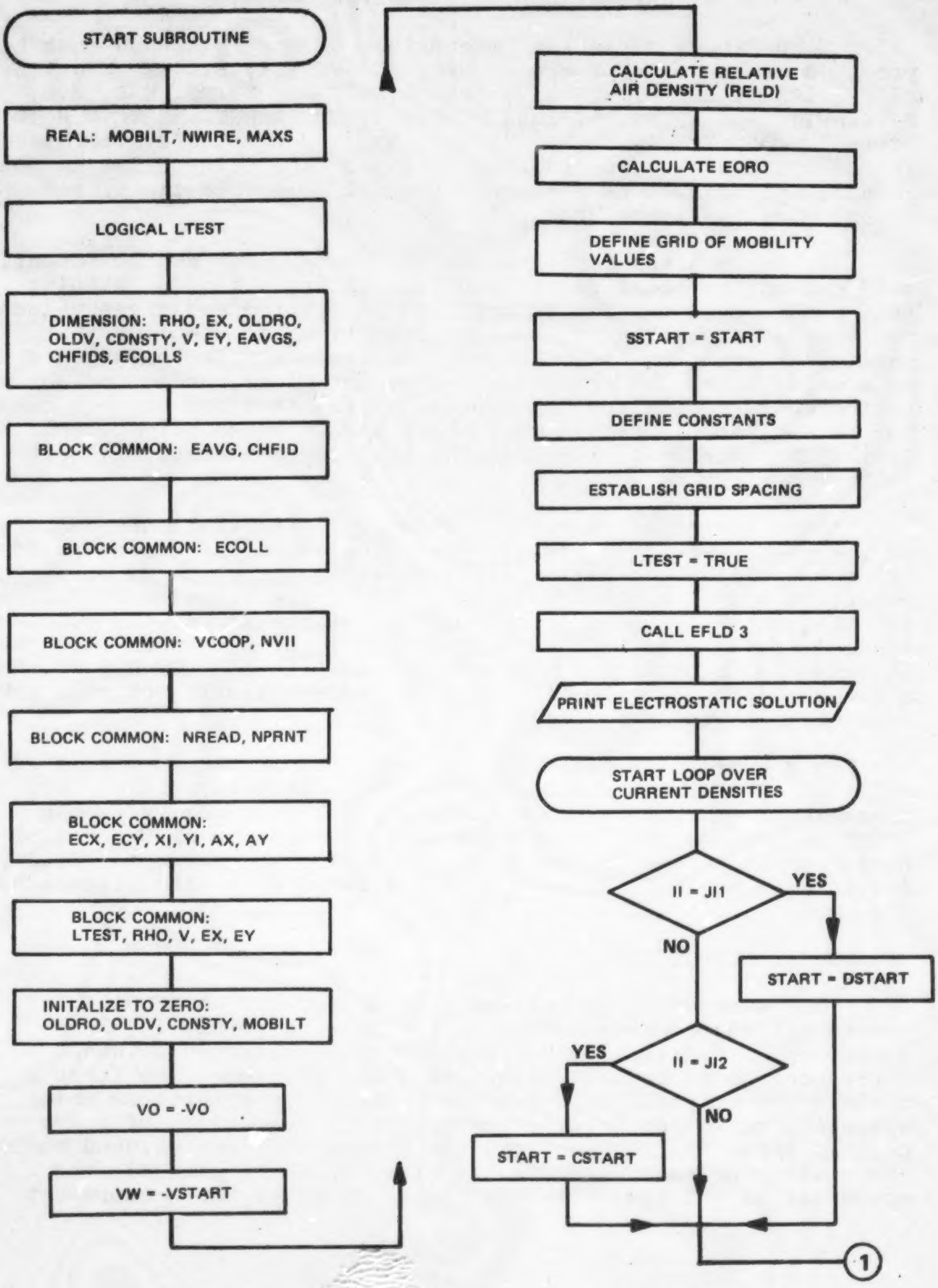
START SUBROUTINE
REAL: MOBILT, NWIRE, MAXS
LOGICAL LTEST
DIMENSION: RHO, EX, OLDRO, OLDV, CDNSTY, V, EY, EAVGS, CHFIDS, ECOLLS
BLOCK COMMON: EAVG, CHFID
BLOCK COMMON: ECOLL
BLOCK COMMON: VCOOP, NVII
BLOCK COMMON: NREAD, NPRNT
BLOCK COMMON: ECX, ECY, XI, YI, AX, AY
BLOCK COMMON: LTEST, RHO, V, EX, EY
INITALIZE TO ZERO: OLDRO, OLDV, CDNSTY, MOBILT
VO = -VO
VW = -VSTART
CALCULATE RELATIVE AIR DENSITY (RELD)
CALCULATE EORO
DEFINE GRID OF MOBILITY VALUES
SSTART = START
DEFINE CONSTANTS
ESTABLISH GRID SPACING
LTEST = TRUE
CALL EFLD 3
PRINT ELECTROSTATIC SOLUTION
START LOOP OVER CURRENT DENSITIES
II = JI1
YES
NO
START = DSTART
II = JI2
YES
NO
START = CSTART
1

Figure 10. Flow chart for subroutine EFLD4 (sheet 1 of 8).

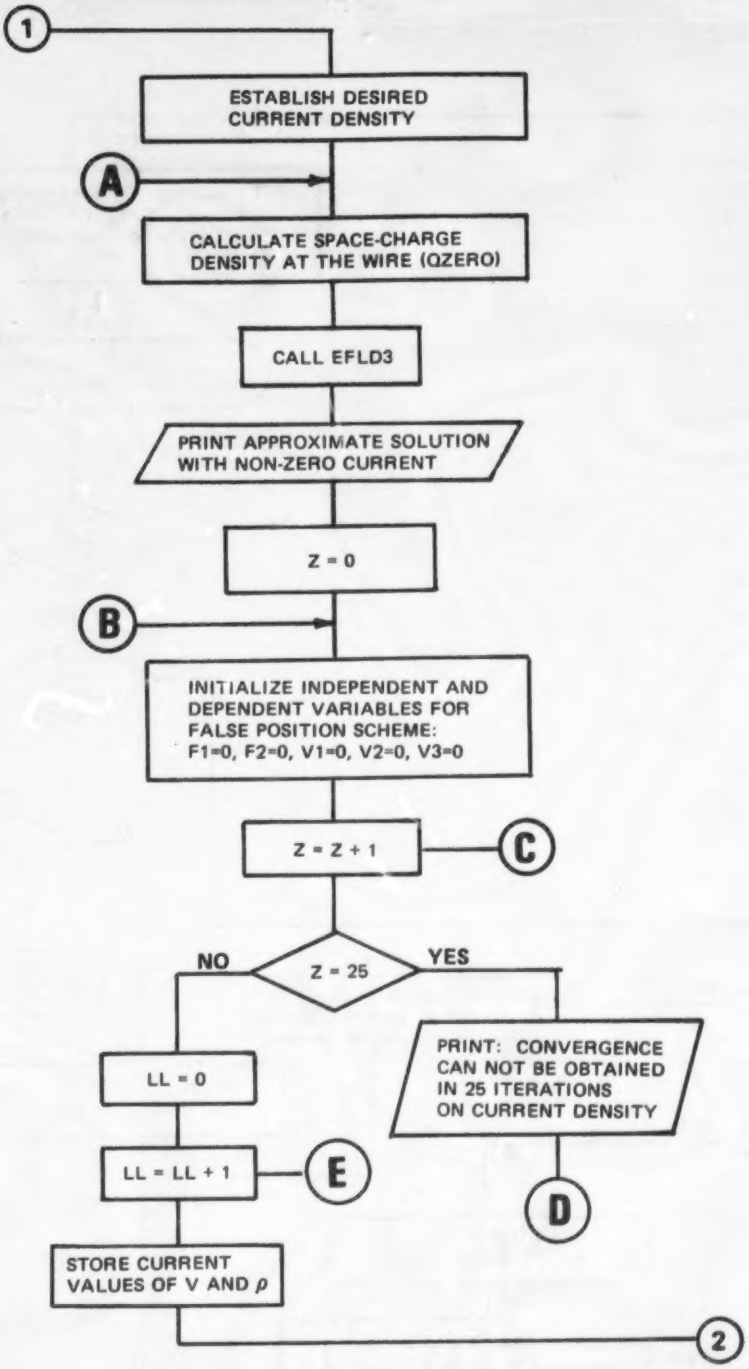
1
ESTABLISH DESIRED CURRENT DENSITY
A
CALCULATE SPACE-CHARGE DENSITY AT THE WIRE (QZERO)
CALL EFLD3
PRINT APPROXIMATE SOLUTION WITH NON-ZERO CURRENT
Z = 0
B
INITIALIZE INDEPENDENT AND DEPENDENT VARIABLES FOR FALSE POSITION SCHEME: F1=0, F2=0, V1=0, V2=0, V3=0
Z = Z + 1
C
NO
Z = 25
YES
PRINT: CONVERGENCE CAN NOT BE OBTAINED IN 25 ITERATIONS ON CURRENT DENSITY
D
LL = 0
LL = LL + 1
E
STORE CURRENT VALUES OF V AND ρ
2

Figure 10. Flow chart for subroutine EFLD4 (sheet 2 of 8).

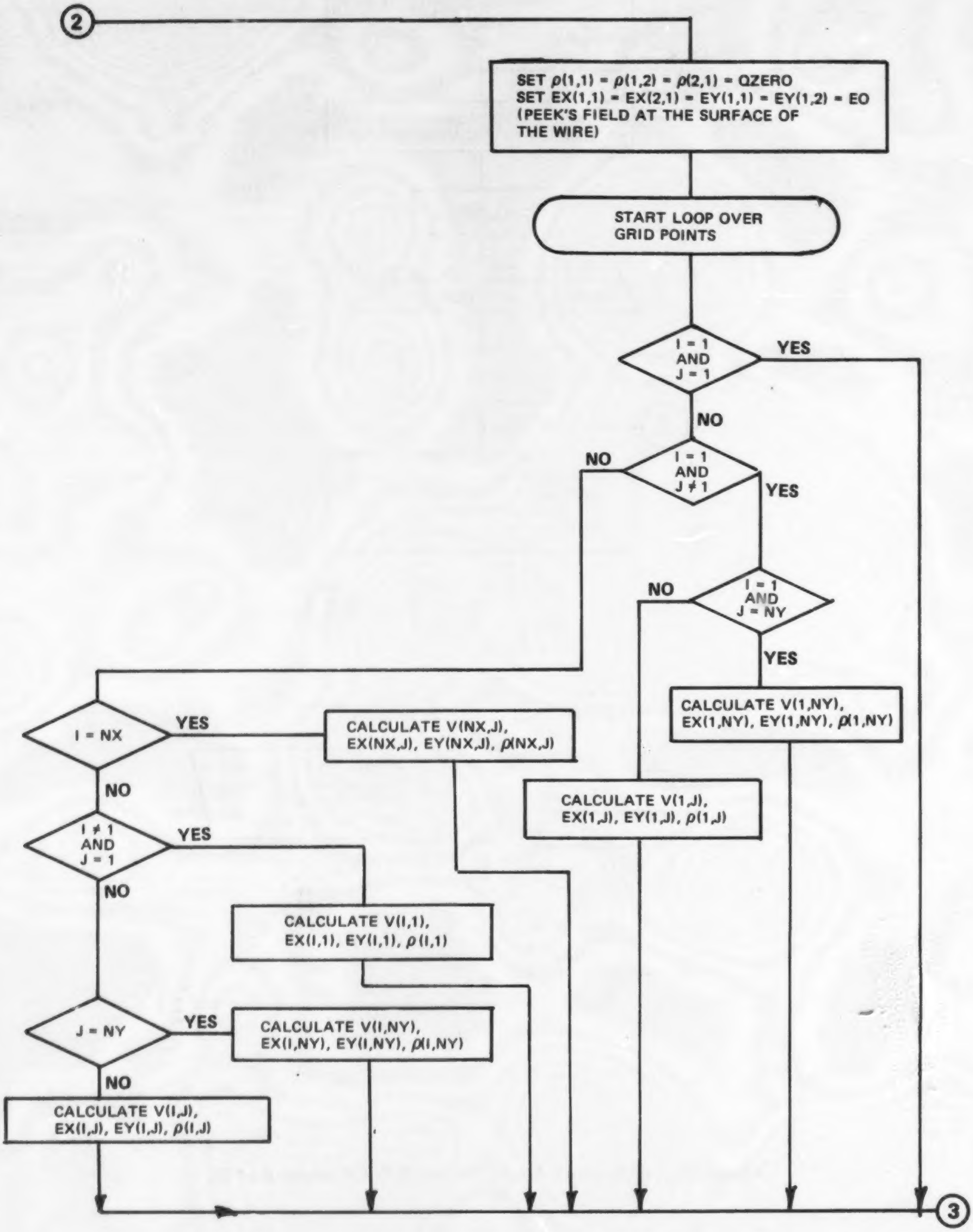
②
SET ρ(1,1) = ρ(1,2) = ρ(2,1) = QZERO
SET EX(1,1) = EX(2,1) = EY(1,1) = EY(1,2) = EO
(PEEK'S FIELD AT THE SURFACE OF THE WIRE)
START LOOP OVER GRID POINTS
I = 1 AND J = 1
YES
NO
I = 1 AND J ≠ 1
NO
YES
I = 1 AND J = NY
NO
YES
CALCULATE V(1,NY), EX(1,NY), EY(1,NY), ρ(1,NY)
CALCULATE V(1,J), EX(1,J), EY(1,J), ρ(1,J)
I = NX
YES
CALCULATE V(NX,J), EX(NX,J), EY(NX,J), ρ(NX,J)
NO
I ≠ 1 AND J = 1
YES
CALCULATE V(I,1), EX(I,1), EY(I,1), ρ (I,1)
NO
J = NY
YES
CALCULATE V(I,NY), EX(I,NY), EY(I,NY), ρ(I,NY)
NO
CALCULATE V(I,J), EX(I,J), EY(I,J), ρ(I,J)
③

Figure 10. Flow chart for subroutine EFLD4 (sheet 3 of 8).

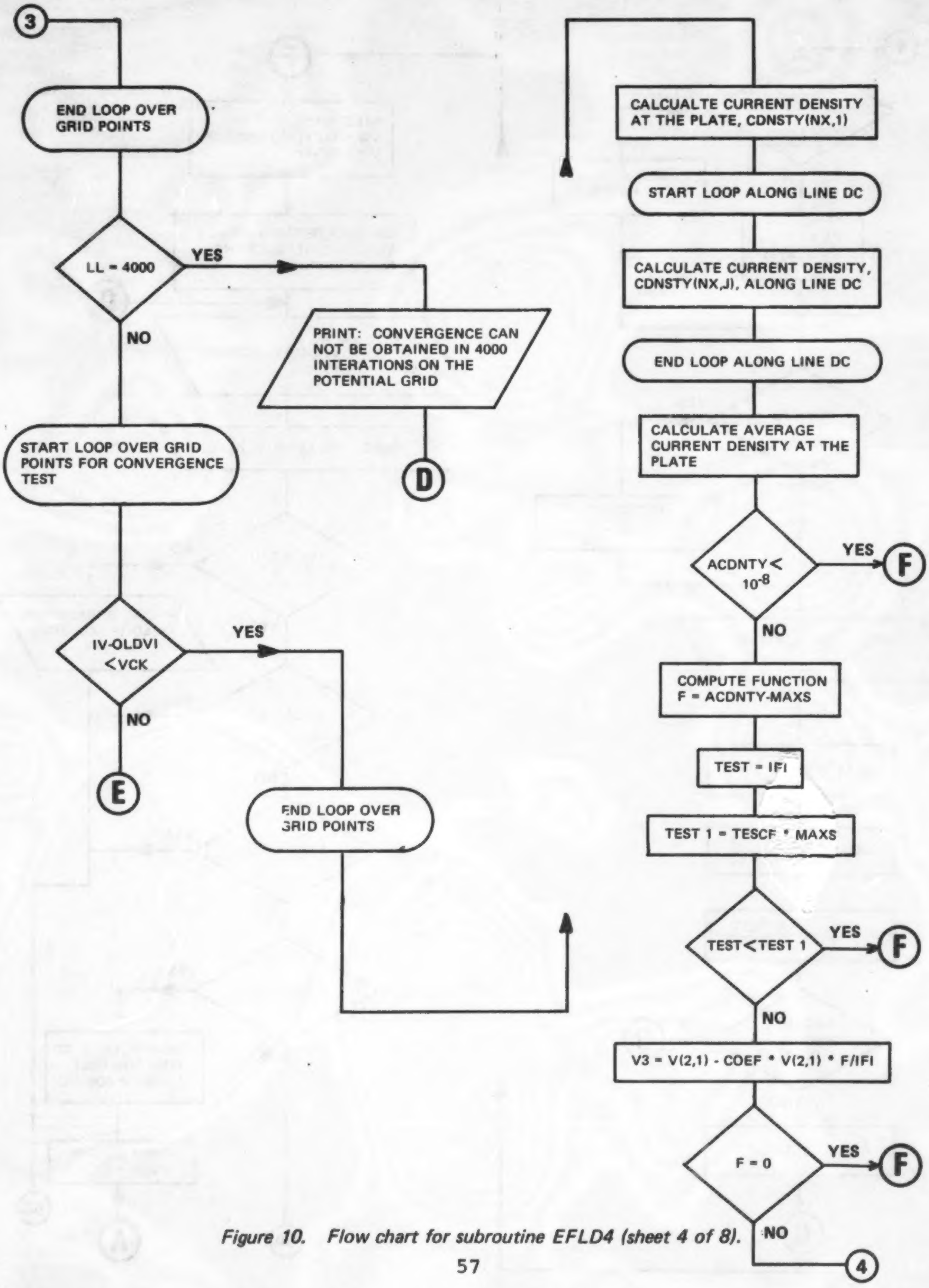
3
END LOOP OVER GRID POINTS
LL = 4000
YES
NO
PRINT: CONVERGENCE CAN NOT BE OBTAINED IN 4000 INTERATIONS ON THE POTENTIAL GRID
D
START LOOP OVER GRID POINTS FOR CONVERGENCE TEST
IV-OLDVI <VCK
YES
NO
E
END LOOP OVER GRID POINTS
CALCUALTE CURRENT DENSITY AT THE PLATE, CDNSTY(NX,1)
START LOOP ALONG LINE DC
CALCULATE CURRENT DENSITY, CDNSTY(NX,J), ALONG LINE DC
END LOOP ALONG LINE DC
CALCULATE AVERAGE CURRENT DENSITY AT THE PLATE
ACDNTY < 10-8
YES
F
NO
COMPUTE FUNCTION F = ACDNTY-MAXS
TEST = IFI
TEST 1 = TESCF * MAXS
TEST<TEST 1
YES
F
NO
V3 = V(2,1) - COEF * V(2,1) * F/IFI
F = 0
YES
F
NO
4

Figure 10. Flow chart for subroutine EFLD4 (sheet 4 of 8).

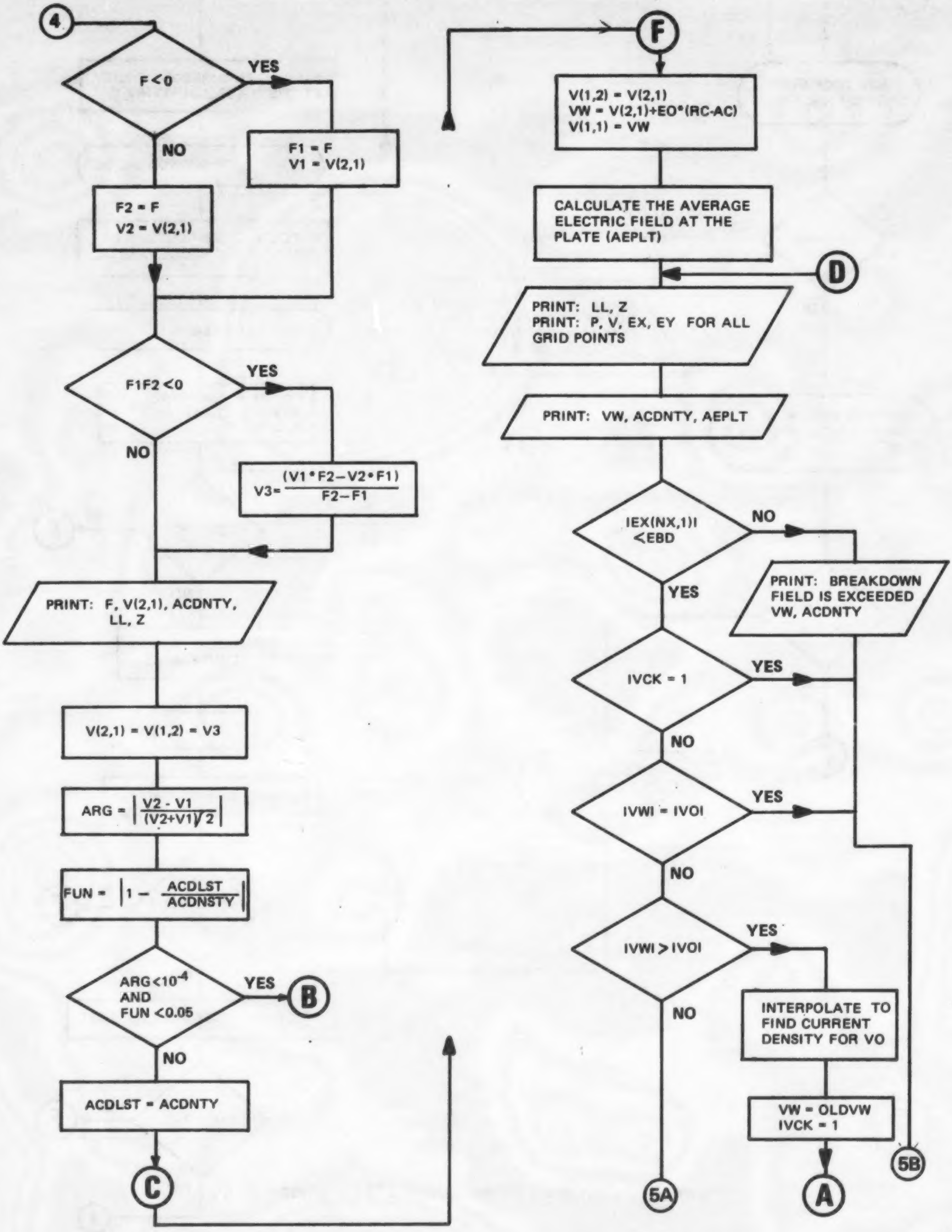
4
F < 0
YES
NO
F1 = F
V1 = V(2,1)
F2 = F
V2 = V(2,1)
F1F2 < 0
YES
NO
V3 = (V1*F2−V2*F1) / (F2−F1)
PRINT: F, V(2,1), ACDNTY, LL, Z
V(2,1) = V(1,2) = V3
ARG = | V2 - V1 / (V2+V1)/2 |
FUN = | 1 − ACDLST / ACDNSTY |
ARG < 10^-4 AND FUN < 0.05
YES
B
NO
ACDLST = ACDNTY
C
F
V(1,2) = V(2,1)
VW = V(2,1)+EO*(RC-AC)
V(1,1) = VW
CALCULATE THE AVERAGE ELECTRIC FIELD AT THE PLATE (AEPLT)
D
PRINT: LL, Z
PRINT: P, V, EX, EY FOR ALL GRID POINTS
PRINT: VW, ACDNTY, AEPLT
|EX(NX,1)| < EBD
NO
YES
PRINT: BREAKDOWN FIELD IS EXCEEDED VW, ACDNTY
IVCK = 1
YES
NO
|VW| = |VO|
YES
NO
|VW| > |VO|
YES
NO
INTERPOLATE TO FIND CURRENT DENSITY FOR VO
VW = OLDVW
IVCK = 1
5A
A
5B

Figure 10. Flow chart for subroutine EFLD4 (sheet 5 of 8).

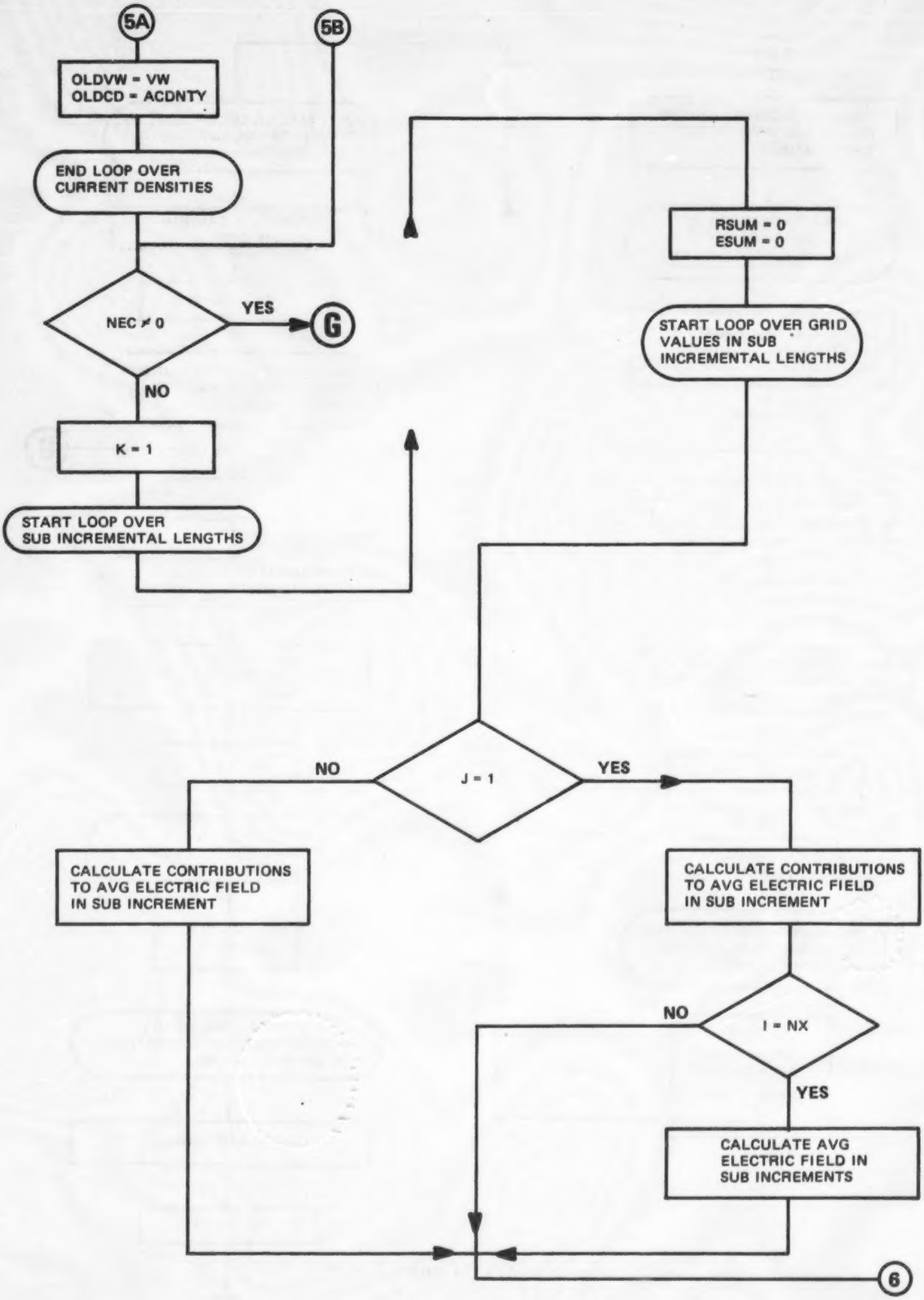
5A
5B
OLDVW = VW
OLDCD = ACDNTY
END LOOP OVER CURRENT DENSITIES
NEC ≠ 0
YES
G
NO
K = 1
START LOOP OVER SUB INCREMENTAL LENGTHS
RSUM = 0
ESUM = 0
START LOOP OVER GRID VALUES IN SUB INCREMENTAL LENGTHS
J = 1
NO
YES
CALCULATE CONTRIBUTIONS TO AVG ELECTRIC FIELD IN SUB INCREMENT
CALCULATE CONTRIBUTIONS TO AVG ELECTRIC FIELD IN SUB INCREMENT
I = NX
NO
YES
CALCULATE AVG ELECTRIC FIELD IN SUB INCREMENTS
6

Figure 10. Flow chart for subroutine EFLD4 (sheet 6 of 8).

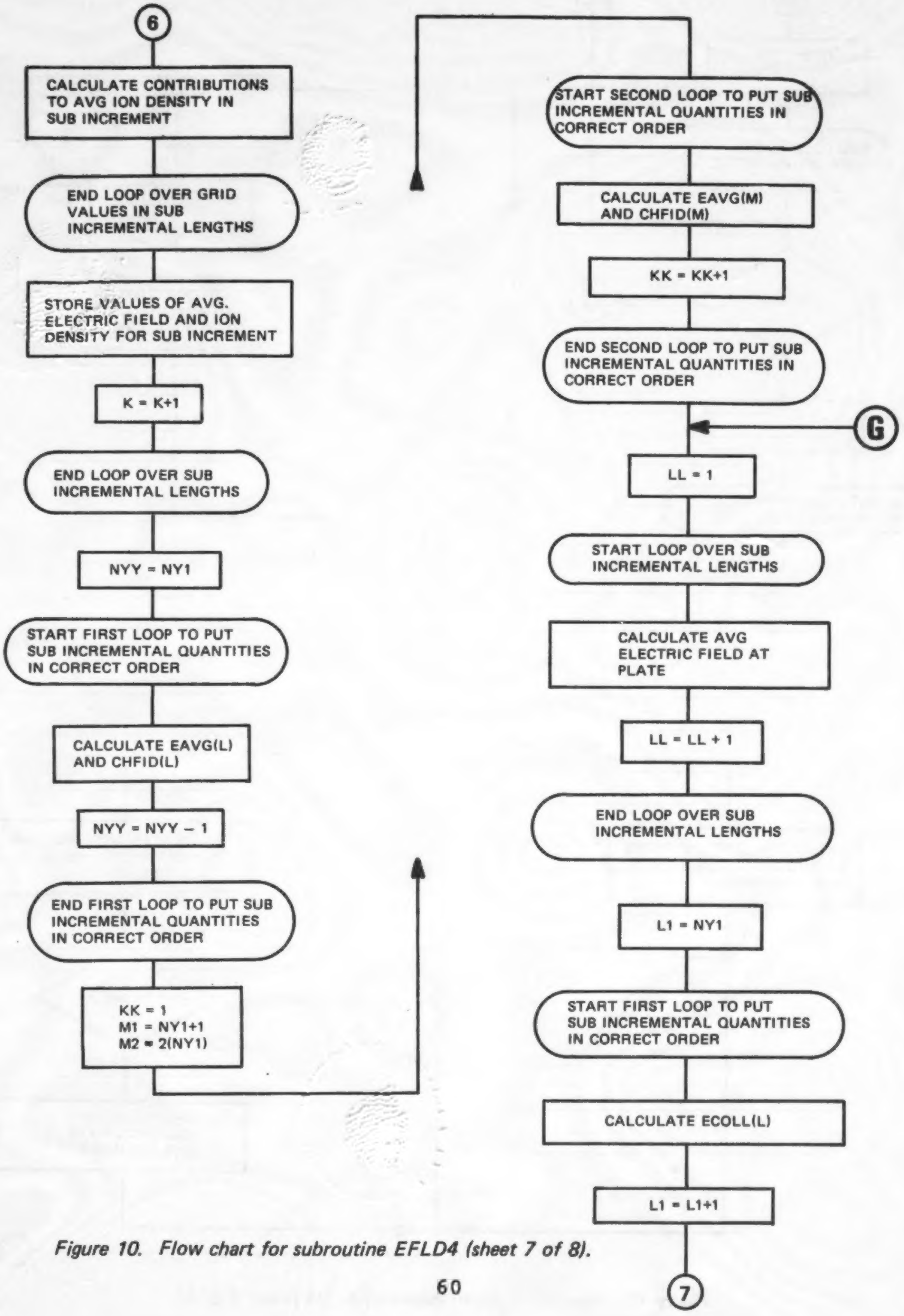
6
CALCULATE CONTRIBUTIONS TO AVG ION DENSITY IN SUB INCREMENT
END LOOP OVER GRID VALUES IN SUB INCREMENTAL LENGTHS
STORE VALUES OF AVG. ELECTRIC FIELD AND ION DENSITY FOR SUB INCREMENT
K = K+1
END LOOP OVER SUB INCREMENTAL LENGTHS
NYY = NY1
START FIRST LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
CALCULATE EAVG(L) AND CHFID(L)
NYY = NYY – 1
END FIRST LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
KK = 1
M1 = NY1+1
M2 = 2(NY1)
START SECOND LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
CALCULATE EAVG(M) AND CHFID(M)
KK = KK+1
END SECOND LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
G
LL = 1
START LOOP OVER SUB INCREMENTAL LENGTHS
CALCULATE AVG ELECTRIC FIELD AT PLATE
LL = LL + 1
END LOOP OVER SUB INCREMENTAL LENGTHS
L1 = NY1
START FIRST LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
CALCULATE ECOLL(L)
L1 = L1+1
7

Figure 10. Flow chart for subroutine EFLD4 (sheet 7 of 8).

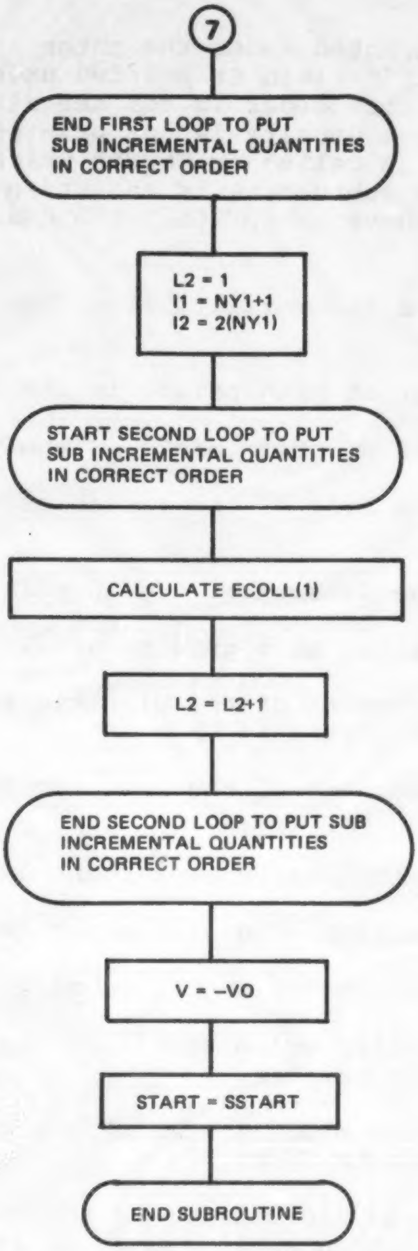
7
END FIRST LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
L2 = 1
I1 = NY1+1
I2 = 2(NY1)
START SECOND LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
CALCULATE ECOLL(1)
L2 = L2+1
END SECOND LOOP TO PUT SUB INCREMENTAL QUANTITIES IN CORRECT ORDER
V = –VO
START = SSTART
END SUBROUTINE

Figure 10. Flow chart for subroutine EFLD4 (sheet 8 of 8).

of electric field is printed under the potential, and the y-component of the electric field is printed under the x-component. The only exception to this order is for the static (zero current) case in which the charge density is not printed. For the static case, this subroutine is called by ENTER2 which is a different entry point. When the subroutine is entered at ENTRY ENTER2 it behaves as described above except that the charge density is not printed.

The following is a sequential list of the calling arguments and their description.

NX - Number of grid points in the x-direction.

NY - Number of grid points in the y-direction.

The following is a list of the variables which are in common with EFLD4.

RHO(I,J) - Charge density at a grid point (c/m^3).

V(I,J) - Potential at a grid point (V).

EX(I,J) - x-component of the electric field at a grid point (V/m).

EY(I,J) - y-component of the electric field at a grid point (V/m).

CDNSTY(NX,J) - Current density at a point on the plate (A/m^2).

X1(I) - x-position of a grid point (m).

Y1(J) - y-position of a grid point (m).

NPRINT - Indicator which specifies the logical unit number of the printer.

EAVG(M) - Average electric field in a given subincrement of length (V/m).

CHFID(M) - Average ion density in the absence of particles in a given subincrement of length ($\#/m^3$).

ECOLL(M) - Average electric field at the plate in a given subincrement of length (V/m).

VCOOP(I,J) - The static-like contribution to the potential at a grid point (V).

ECX(I,J) - The x-component of the static electric field at a grid point (V/m).

ECY(I,J) - The y-component of the static electric field at a grid point (V/m).

AX(I) - The distance between the I-th and I+1-st grid points in the x-direction (m). This is used only with EFLD4.

AY(J) - The distance between the J-th and the J+1-st grid points in the y-direction (m). This is used only with EFLD4.

Figure 11 shows a detailed flow chart of this subroutine. A listing of this subroutine is given in Appendix D.

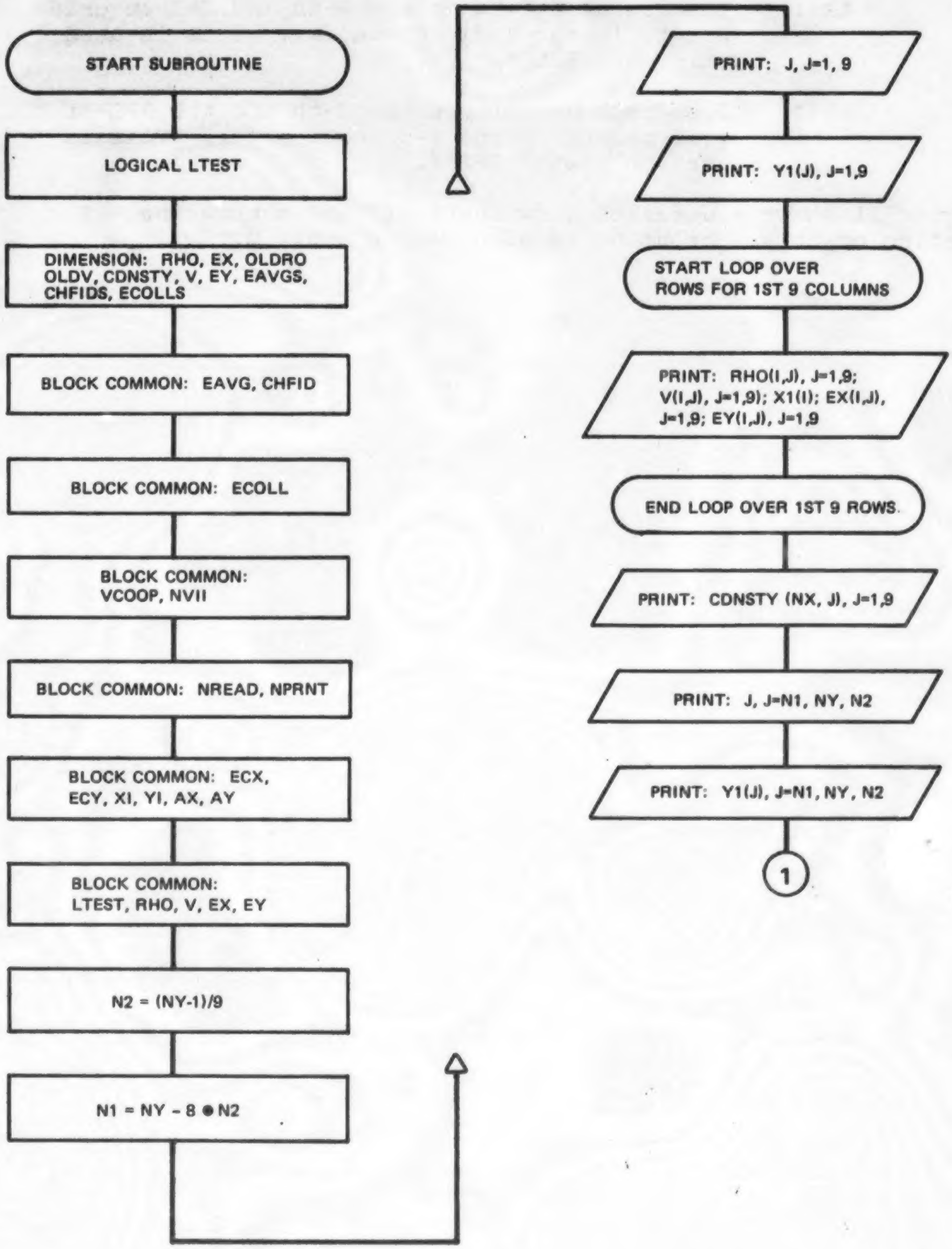
START SUBROUTINE
LOGICAL LTEST
DIMENSION: RHO, EX, OLDRO OLDV, CDNSTY, V, EY, EAVGS, CHFIDS, ECOLLS
BLOCK COMMON: EAVG, CHFID
BLOCK COMMON: ECOLL
BLOCK COMMON: VCOOP, NVII
BLOCK COMMON: NREAD, NPRNT
BLOCK COMMON: ECX, ECY, XI, YI, AX, AY
BLOCK COMMON: LTEST, RHO, V, EX, EY
N2 = (NY-1)/9
N1 = NY - 8 ● N2
PRINT: J, J=1, 9
PRINT: Y1(J), J=1,9
START LOOP OVER ROWS FOR 1ST 9 COLUMNS
PRINT: RHO(I,J), J=1,9; V(I,J), J=1,9); X1(I); EX(I,J), J=1,9; EY(I,J), J=1,9
END LOOP OVER 1ST 9 ROWS
PRINT: CDNSTY (NX, J), J=1,9
PRINT: J, J=N1, NY, N2
PRINT: Y1(J), J=N1, NY, N2
1

Figure 11. Flow chart for subroutine OUTPUT (sheet 1 of 3).

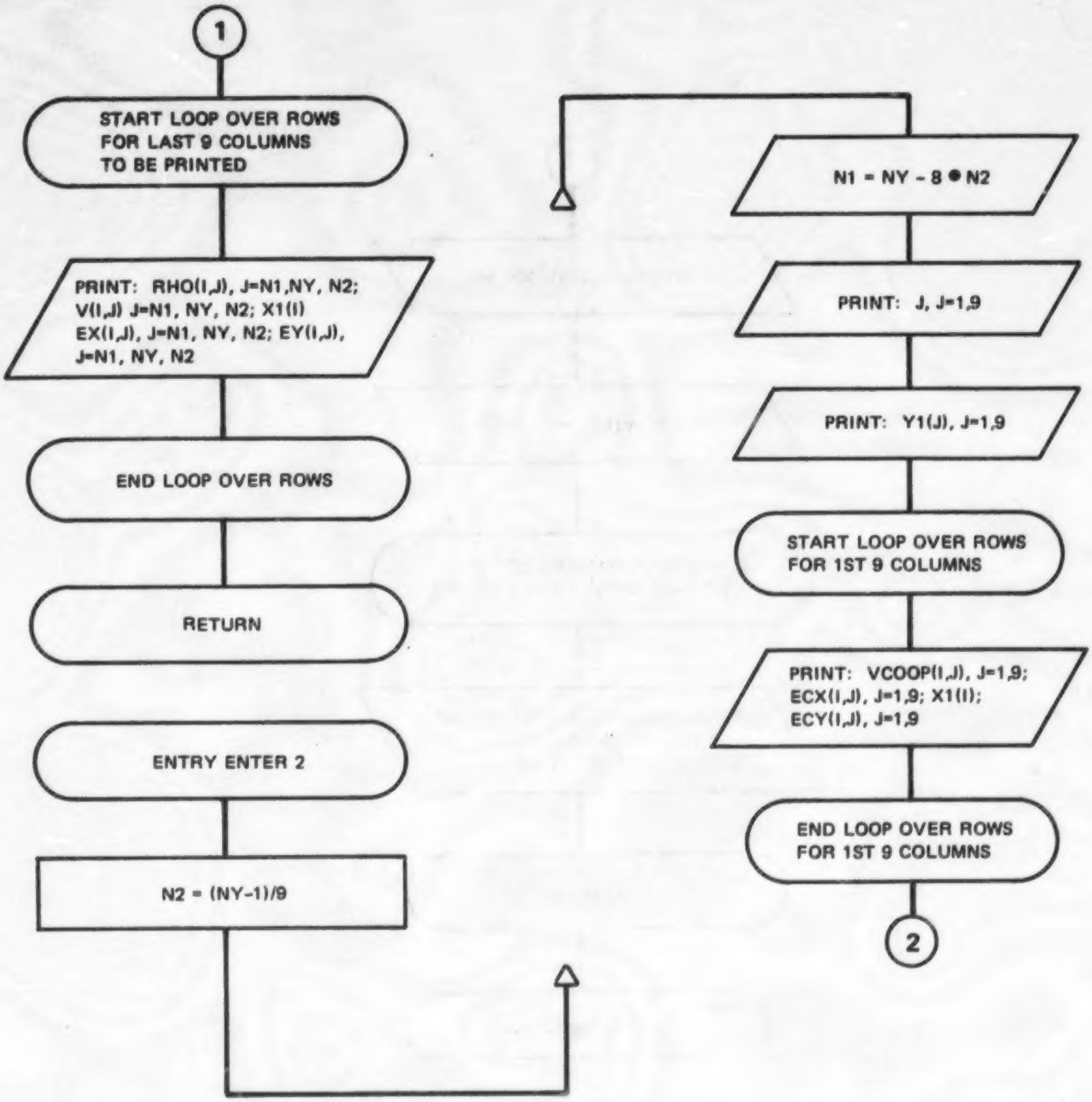
1
START LOOP OVER ROWS FOR LAST 9 COLUMNS TO BE PRINTED
PRINT: RHO(I,J), J=N1,NY, N2; V(I,J) J=N1, NY, N2; X1(I) EX(I,J), J=N1, NY, N2; EY(I,J), J=N1, NY, N2
END LOOP OVER ROWS
RETURN
ENTRY ENTER 2
N2 = (NY-1)/9
N1 = NY - 8 ● N2
PRINT: J, J=1,9
PRINT: Y1(J), J=1,9
START LOOP OVER ROWS FOR 1ST 9 COLUMNS
PRINT: VCOOP(I,J), J=1,9; ECX(I,J), J=1,9; X1(I); ECY(I,J), J=1,9
END LOOP OVER ROWS FOR 1ST 9 COLUMNS
2

Figure 11. Flow chart for subroutine OUTPUT (sheet 2 of 3).

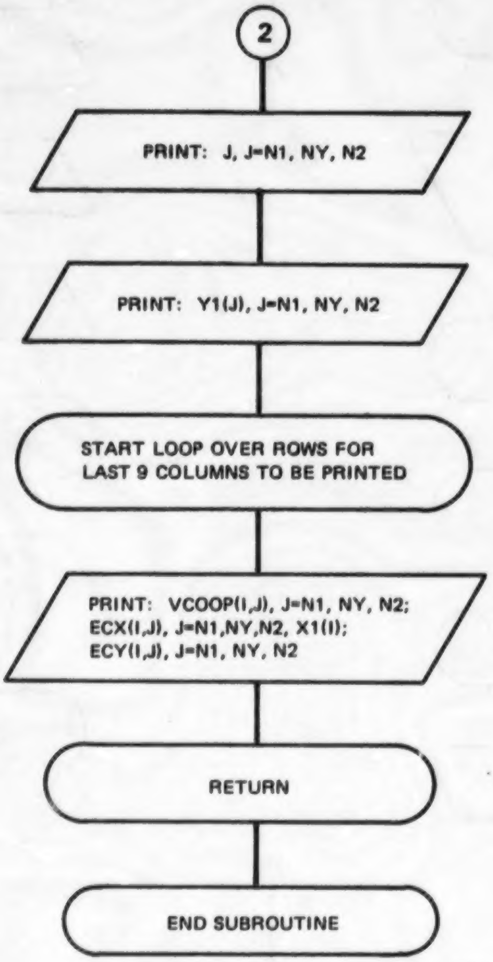
2
PRINT: J, J=N1, NY, N2
PRINT: Y1(J), J=N1, NY, N2
START LOOP OVER ROWS FOR LAST 9 COLUMNS TO BE PRINTED
PRINT: VCOOP(I,J), J=N1, NY, N2; ECX(I,J), J=N1,NY,N2, X1(I); ECY(I,J), J=N1, NY, N2
RETURN
END SUBROUTINE

Figure 11. Flow chart for subroutine OUTPUT (sheet 3 of 3).

SECTION 6

GAUSSIAN QUADRATURE INTEGRATION FOR COMPUTING PARTICLE CHARGING RATES

Previously, the RATE function subprogram has used Simpson's rule to perform the numerical integration over the angle θ. RATE has been rewritten using the Gaussian quadrature method to perform this integration since the same accuracy can be obtained using fewer increments than would be required by Simpson's rule. This reduction in the number of integration increments results in a significant saving of computer time. Also, by reducing the number of increments used in the Runga-Kutta integration which is used to integrate the charging rate over time a further reduction in the amount of time required to compute particle charge is accomplished.

Previously, 10 increments in the Runga-Kutta integration and 20 increments in Simpson's rule were recommended in order to obtain sufficient accuracy in the model projections. Comparable accuracy can be obtained using five increments in the Runga-Kutta integration and three increments in the new Gaussian integration. A detailed comparison of the two integration schemes using different numbers of integration increments is shown in Table 2. The charges computed by the different schemes are given for several particle diameters as well as for several positions within the precipitator. The difference in the charge computed by the two methods for various particle diameters is negligible for smaller particle diameters (.1 - 5 micrometers) and increases to the order of 2% for larger particle diameters (20 - 30 micrometers). These differences in accumulated charge have a negligible effect on such quantities as efficiency, effluent MMD, and particle standard deviation since the major differences occur at particle diameters which are easily collected by the precipitation process. In the next section a description of the new RATE function is given.

FUNCTION SUBPROGRAM RATE

This function subprogram calculates the right hand side of

$$\frac{dq}{dt} = \frac{N_o e b q_s}{4\varepsilon_o} \left(1 - \frac{q}{q_s}\right)^2$$

TABLE 2. CHARGE ON PARTICLES COMPUTED BY DIFFERENT INTEGRATION METHODS

Particle Radius (10^{-6}m)	Length Increment of Precipitator	Particle Charge (10^{-18} Coul) 10 Inc. Runga-Kutta 20 Inc. Simpson's Time/Loop ≈ 5.5 sec	20 Inc. Runga-Kutta 40 Inc. Simpson's Time/Loop ≈ 22 sec	10 Inc. Runga-Kutta 5 Pt. Gaussian Time/Loop ≈ 1.4 sec	5 Inc. Runga-Kutta 5 Pt. Gaussian Time/Loop ≈ 0.7 sec	5 Inc. Runga-Kutta 3 Pt. Gaussian Time/Loop ≈ 0.4 sec
0.2	1	0.017469	0.017447	0.017428	0.017452	0.017459
	10	0.035541	0.035536	0.035531	0.035533	0.035534
	20	0.041324	0.041322	0.041320	0.041321	0.041309
	27	0.043734	0.043733	0.043732	0.043733	0.043715
0.7	1	0.14605	0.14574	0.14563	0.14633	0.14636
	10	0.26117	0.26112	0.26107	0.26109	0.25923
	20	0.28877	0.28876	0.28873	0.28874	0.28661
	27	0.29881	0.29880	0.29878	0.29879	0.29658
1.6	1	0.69225	0.69001	0.68934	0.69215	0.69278
	10	1.0918	1.0912	1.0911	1.0912	1.0838
	20	1.1742	1.1740	1.1745	1.1745	1.1682
	27	1.1857	1.1856	1.1862	1.1862	1.1801
3.5	1	3.1898	3.1756	3.1701	3.1822	3.1816
	10	4.5682	4.5534	4.5282	4.5284	4.5578
	20	4.7153	4.7266	4.7183	4.7184	4.7528
	27	4.7153	4.7266	4.7183	4.7184	4.7528
8.5	1	18.618	18.518	18.474	18.548	18.547
	10	26.097	25.920	25.363	25.364	25.358
	20	26.506	26.399	25.832	25.832	25.827
	27	26.506	26.399	25.832	25.832	25.827
20.	1	102.97	102.40	102.15	102.56	102.59
	10	144.39	143.36	140.25	140.26	140.26
	20	146.65	146.04	142.84	142.84	142.84
	27	146.65	146.04	142.84	142.84	142.84

$$+ \frac{\pi a^2 \tilde{v} N_o e}{2} \int_{\theta_o}^{\pi/2} \exp\left[\left(\frac{qe(r_o - a)}{4\pi\varepsilon_o kTar_o}\right.\right.$$

$$\left.\left. + \frac{[3ar_o^2 - r_o^3(K + 2) + a^3(K - 1)]eE_a\cos\theta}{kTr_o^2\ (K + 2)}\right)\right]\sin\theta d\theta$$

$$+ \frac{\pi a^2 \tilde{v} N_o e}{2} \exp\left(-qe/4\pi\varepsilon_o akT\right) , \tag{45}$$

where $$q_s = 4\pi\varepsilon_o E_a a^2 \left(1 + 2\,\frac{K-1}{K+2}\right) , \tag{46}$$

$$\theta_o = \arccos\left(q/q_s\right) , \tag{47}$$

and q = instantaneous charge on the particle (C),

q_s = saturation charge due to field charging (C),

θ = azimuthal angle in a spherical coordinate system with origin at the center of the particle (radians),

θ_o = maximum azimuthal angle for which electric field lines enter the particle (radians),

N_o = free ion density (m^{-3}),

e = electronic charge (C),

ε_o = permittivity of free space ($C^2/N\text{-}m^2$),

E_a = average electric field between the electrodes (V/m),

b = ion mobility ($m^2/V\text{-}sec$),

$\tilde{v}$ = mean thermal speed of ions (m/sec),

a = particle radius (m),

k = Boltzmann's constant (J/°K),

T = absolute temperature (°K),

t = time (sec),

K = dielectric constant of the particle, and

r_o = radial distance along θ at which the radial component of the total electric field is zero (m).

The above equation is used in subroutine CHARGN. In order to use this function subprogram, subroutines ARCCOS and ZERO must be supplied.

The first and third terms on the right hand side of equation (45) are calculated in a straight forward manner. However, the third term involves an integration over the angle θ which must be performed numerically.[19] The integration is performed by using the Gaussian quadrature which is given by

$$\int_{\theta_o}^{\pi/2} f(\theta)d\theta = \frac{\pi/2 - \theta_o}{2} \int_{-1}^{1} F(t)dt \quad , \qquad (48)$$

where

$$\theta = \tfrac{1}{2}(\pi/2 - \theta_o)t + \tfrac{1}{2}(\theta_o + \pi/2) \quad , \qquad (49)$$

and the integral

$$\int_{-1}^{1} F(t)dt = A_oF(t_o) + A_1F(t_1) + \cdots\cdots A_nF(t_n) \qquad (50)$$

is evaluated using tabulated values of $A_k (k = 0,1 \cdots\cdots n)$ and $t_k (k = 0,1 \cdots\cdots n)$. The subprogram performs the operations indicated in equations (48) and (50) for a fixed number of points, n = 3.

If the charge on the particle is equal to or greater than the saturation charge, the first term on the right hand side of equation (45) is set equal to zero. Once the three terms on the right hand side of equation (45) are calculated, then they are added to give the total charging rate.

Figure 12 shows a detailed flow chart for this subprogram. All information which is transmitted between subroutine CHARGN and this function subprogram is transferred through calling arguments. The following is a sequential list of the calling arguments and their descriptions.

ECHARG - Value of an electronic charge unit (C).

SCHARG - Value of saturation charge number from the field charging equation (see equation 46).

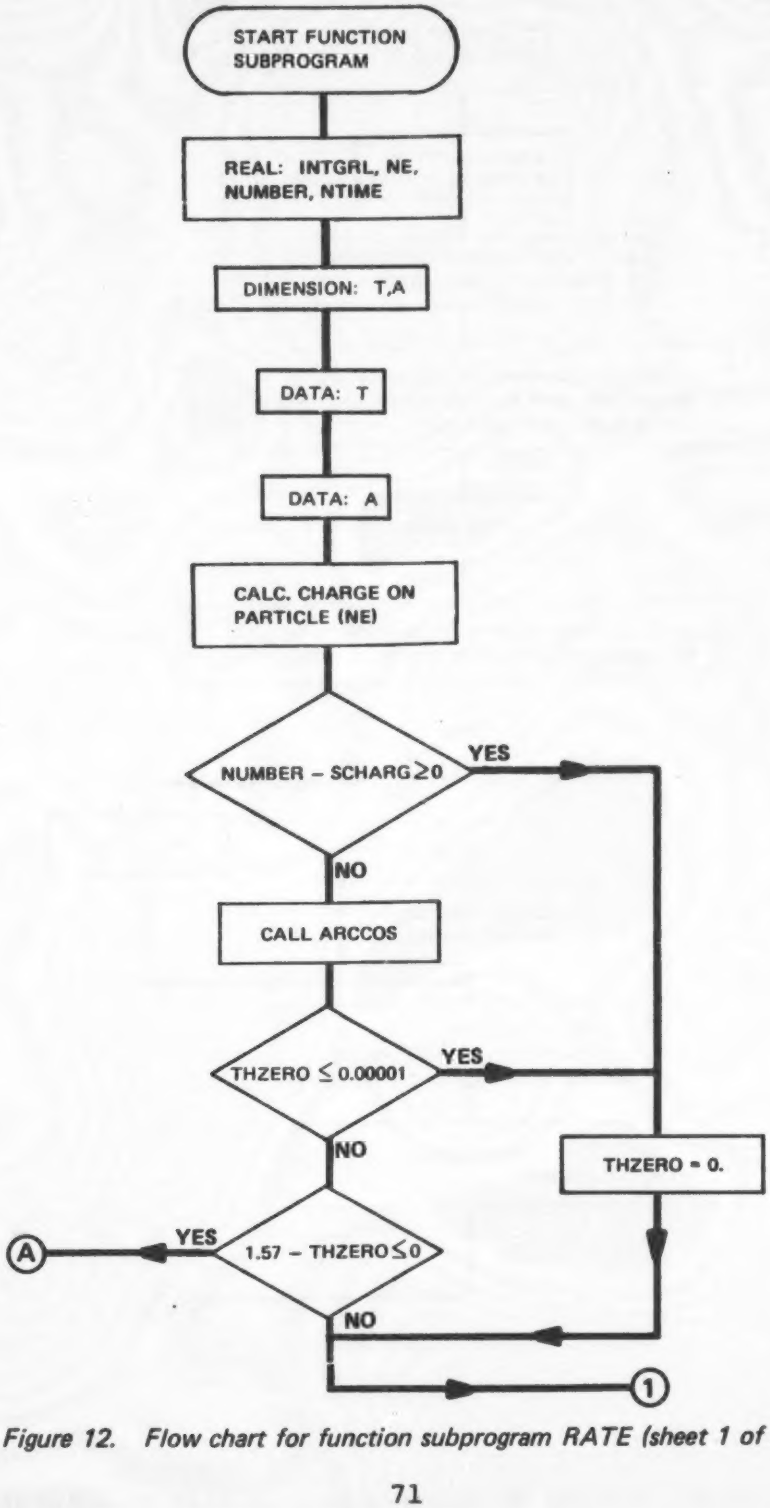

Figure 12. Flow chart for function subprogram RATE (sheet 1 of 3).

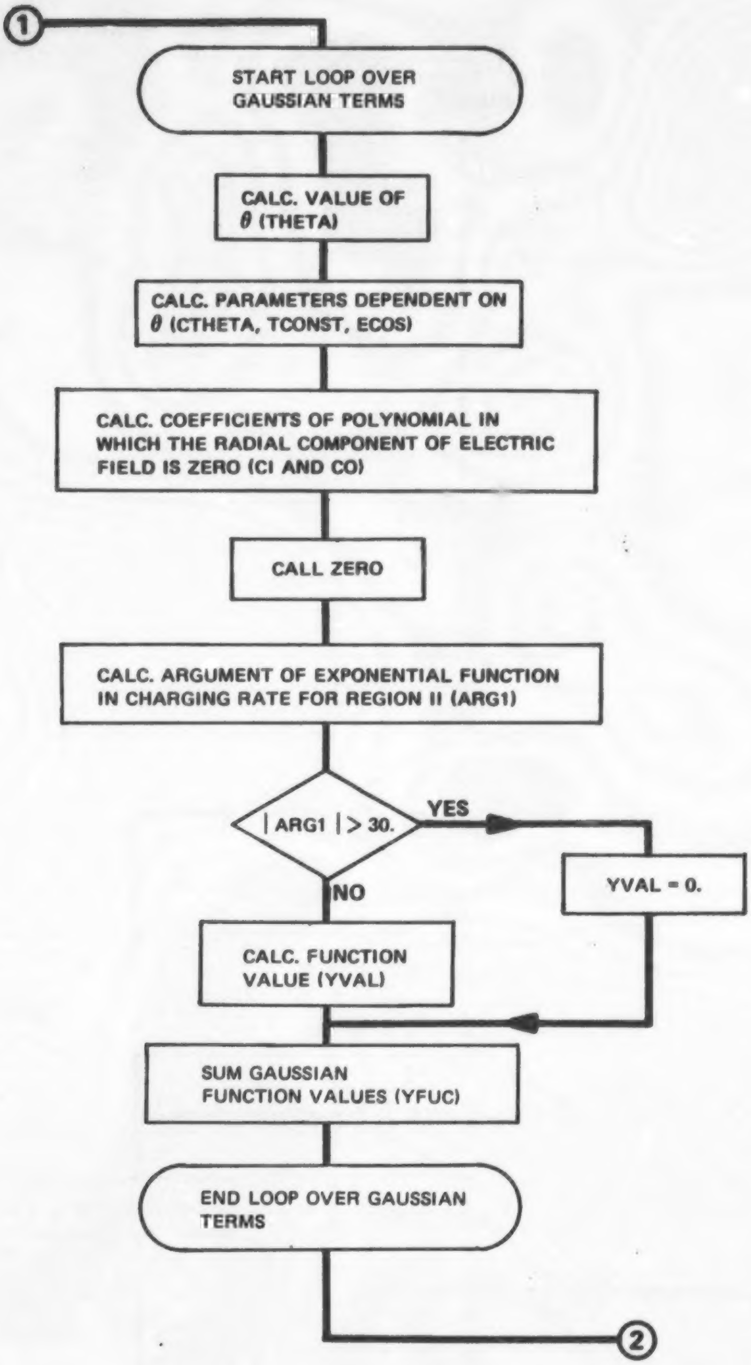
①
START LOOP OVER GAUSSIAN TERMS
CALC. VALUE OF θ (THETA)
CALC. PARAMETERS DEPENDENT ON θ (CTHETA, TCONST, ECOS)
CALC. COEFFICIENTS OF POLYNOMIAL IN WHICH THE RADIAL COMPONENT OF ELECTRIC FIELD IS ZERO (CI AND CO)
CALL ZERO
CALC. ARGUMENT OF EXPONENTIAL FUNCTION IN CHARGING RATE FOR REGION II (ARG1)
\| ARG1 \| > 30.
YES
YVAL = 0.
NO
CALC. FUNCTION VALUE (YVAL)
SUM GAUSSIAN FUNCTION VALUES (YFUC)
END LOOP OVER GAUSSIAN TERMS
②

Figure 12. Flow chart for function subprogram RATE (sheet 2 of 3).

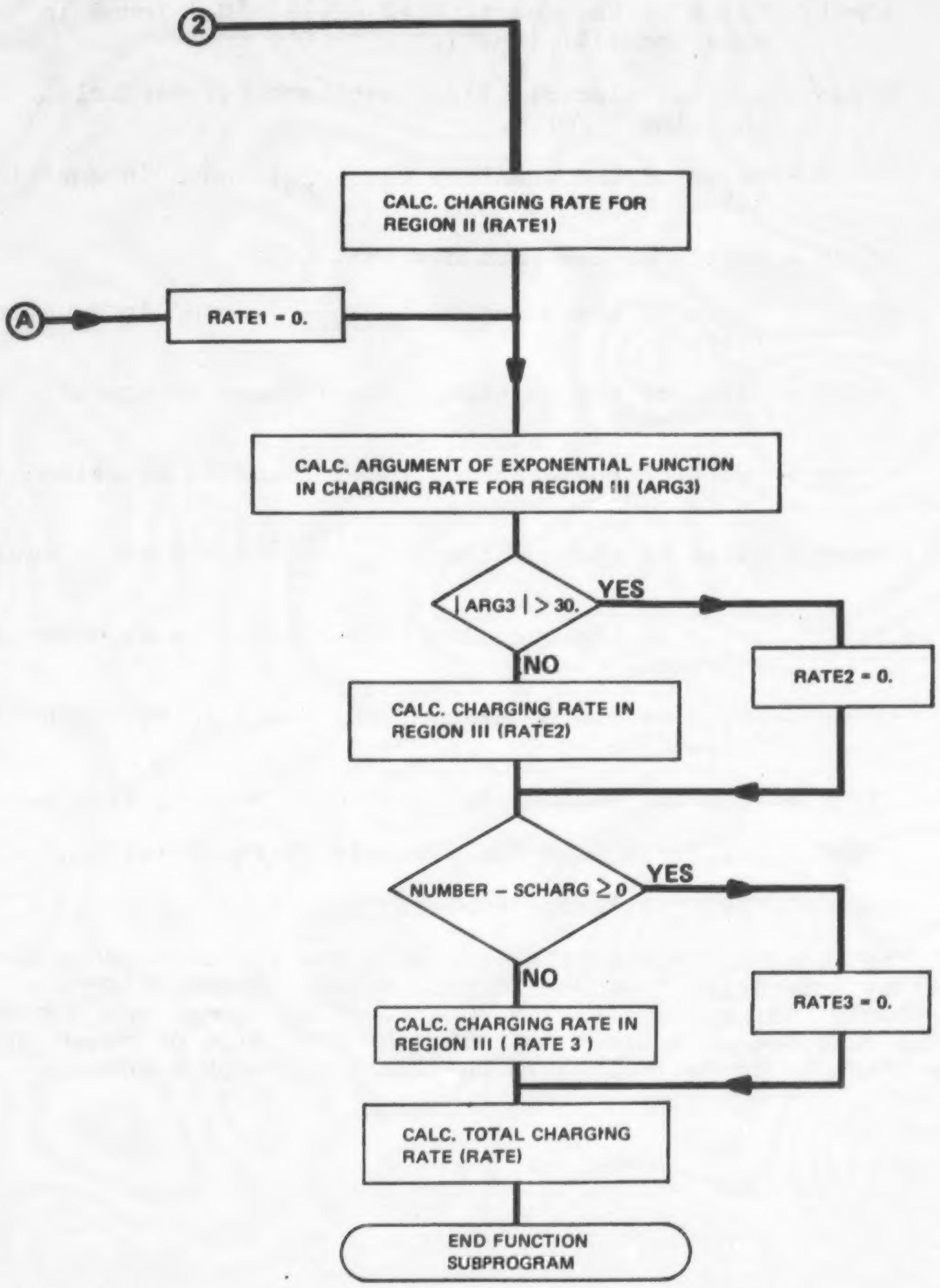
2
CALC. CHARGING RATE FOR REGION II (RATE1)
A
RATE1 = 0.
CALC. ARGUMENT OF EXPONENTIAL FUNCTION IN CHARGING RATE FOR REGION III (ARG3)
| ARG3 | > 30.
YES
NO
RATE2 = 0.
CALC. CHARGING RATE IN REGION III (RATE2)
NUMBER – SCHARG ≥ 0
YES
NO
RATE3 = 0.
CALC. CHARGING RATE IN REGION III (RATE 3)
CALC. TOTAL CHARGING RATE (RATE)
END FUNCTION SUBPROGRAM

Figure 12. Flow chart for function subprogram RATE (sheet 3 of 3).

CONST - Value of the quantity $[2\,\frac{(K-1)}{(K+2)}\,a^3E_0]$ found in equation (46) $[\text{V-m}^2]$.

EZERO - Applied electric field strength for particle charging (V/m).

V - Value of the quantity $[\frac{e^2}{4\pi\varepsilon_0 akT}]$ found in equation (45).

RSIZE - Radius of the particle (m).

ECONST - Value of the quantity $[\frac{3eE_0a}{kT(K+2)}]$ found in equation (45).

CMKS - Value of the quantity $[4\pi\varepsilon_0]$ found in equation (45) $(C^2/\text{nt-m}^2)$.

RR - Value of the quantity $[\frac{eE_0}{kT}]$ found in equation (45) $[m^{-1}]$.

FCONST - Value of the quantity $[\frac{(K-1)eE_0a^3}{(K+2)kT}]$ found in equation (45) $[m^2]$.

FACTOR - Value of the quantity $[\frac{\pi\tilde{v}a^2}{2}]$ found in equation (45) $[m^3/\text{sec}]$.

COEFF - Value of the quantity $[\frac{bq_s}{4E_0}]$ found in equation (45) $[m^3/\text{sec}]$.

AFID - Free ion density for particle charging $(\#/m^3)$.

NTIME - Residence time for particle charging (sec).

NUMBER - Particle charge number.

Of the above variables, the values of the following must be provided by subroutine CHARGN: ECHARG, SCHARG, CONST, EZERO, V, RSIZE, ECONST, RR, FCONST, FACTOR, COEFF, AFID, NTIME, and NUMBER. The total charging rate given on the right hand side of equation (45) is RATE and is determined in the function subprogram.

SECTION 7

EFFECTS OF THE NEW MODIFICATIONS ON THE PREDICTIONS OF THE MODEL

DISCUSSIONS

Two of the modifications described earlier in this report have been incorporated into the working version of the computer program which represents the mathematical model of electrostatic precipitation. The analytic approximations to the electrical solutions in a wire-plate geometry have been incorporated into a subroutine called EFLD3. This subprogram has been included in the program with several options. When EFLD3 is used, the calculation performed is completely analogous to that in either EFLD1 or EFLD2, except that the analytic approximations are used to replace the numerical solutions. The subroutine CMAN along with the modifications described earlier was substituted for its original version. The Gaussian Quadratures integration scheme for computing the charge on particles has also been included in the program. This integration method has the effect of speeding up the charge calculations but should not give rise to any noticeable change in the results of the model predictions.

Although a new numerical integration scheme was described in Section 5 and has been listed in Appendix C, it has not been included in the computer program for modeling electrostatic precipitators. This new numerical solution was used primarily to test the previous numerical solution and the approximate solution. The subprogram listed in Appendix C could be substituted for EFLD2 in the computer program if one so desired. Such a step is not considered practical, since the program would then require even more time than before to execute. The new numerical method may prove valuable, however, in developing further extensions to the mathematical model.

A complete listing of the new version of the computer program for modeling wire-plate electrostatic precipitators is given in Appendix F. A list giving the definitions of variables used in the program is given in Appendix O. This program differs from the one listed in the previous model report mainly in that it contains the new subroutine EFLD3 and has new versions of the subroutine CMAN and the function subprogram RATE. A simplified flow chart for the entire program is shown in Figure 13.

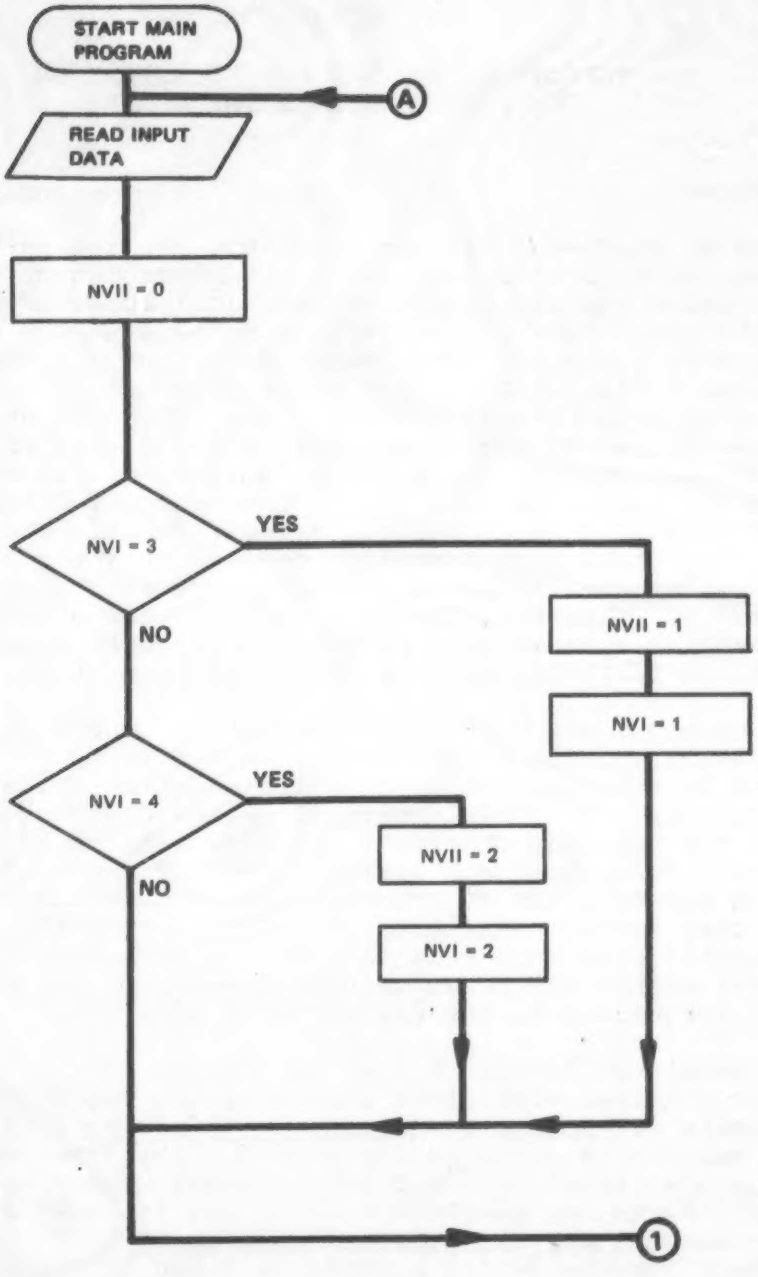

Figure 13. Simplified flow chart for logic of the entire program (sheet 1 of 7).

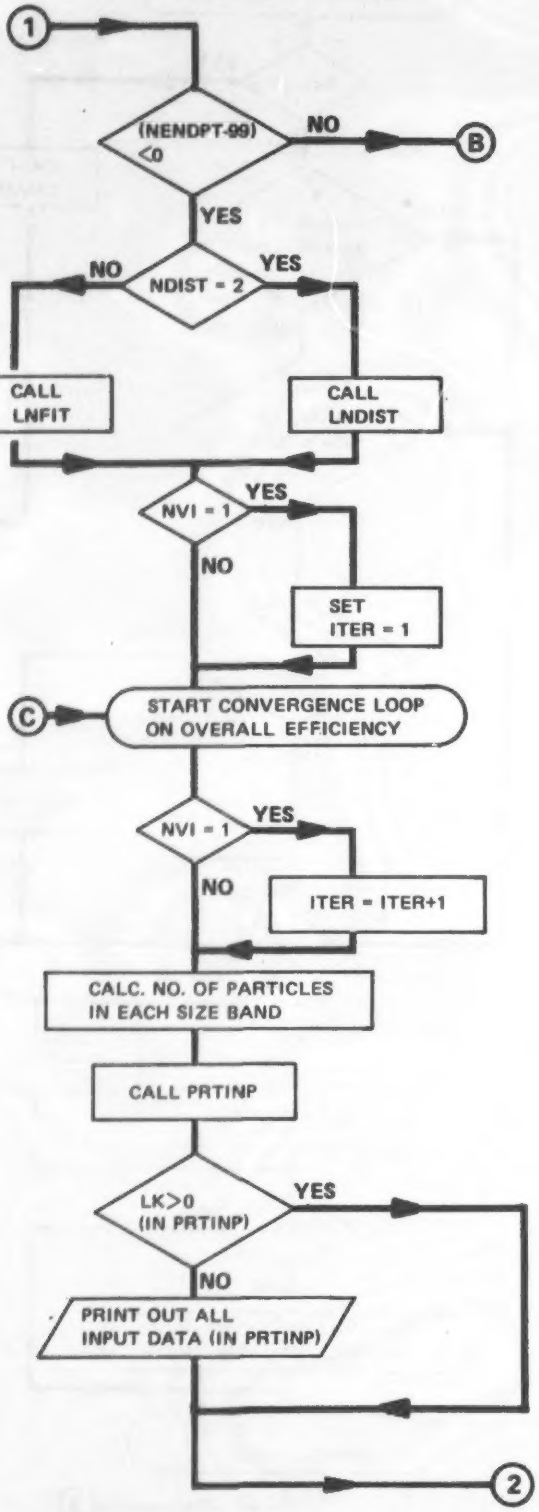

Figure 13. Simplified flow chart for logic of the entire program (sheet 2 of 7).

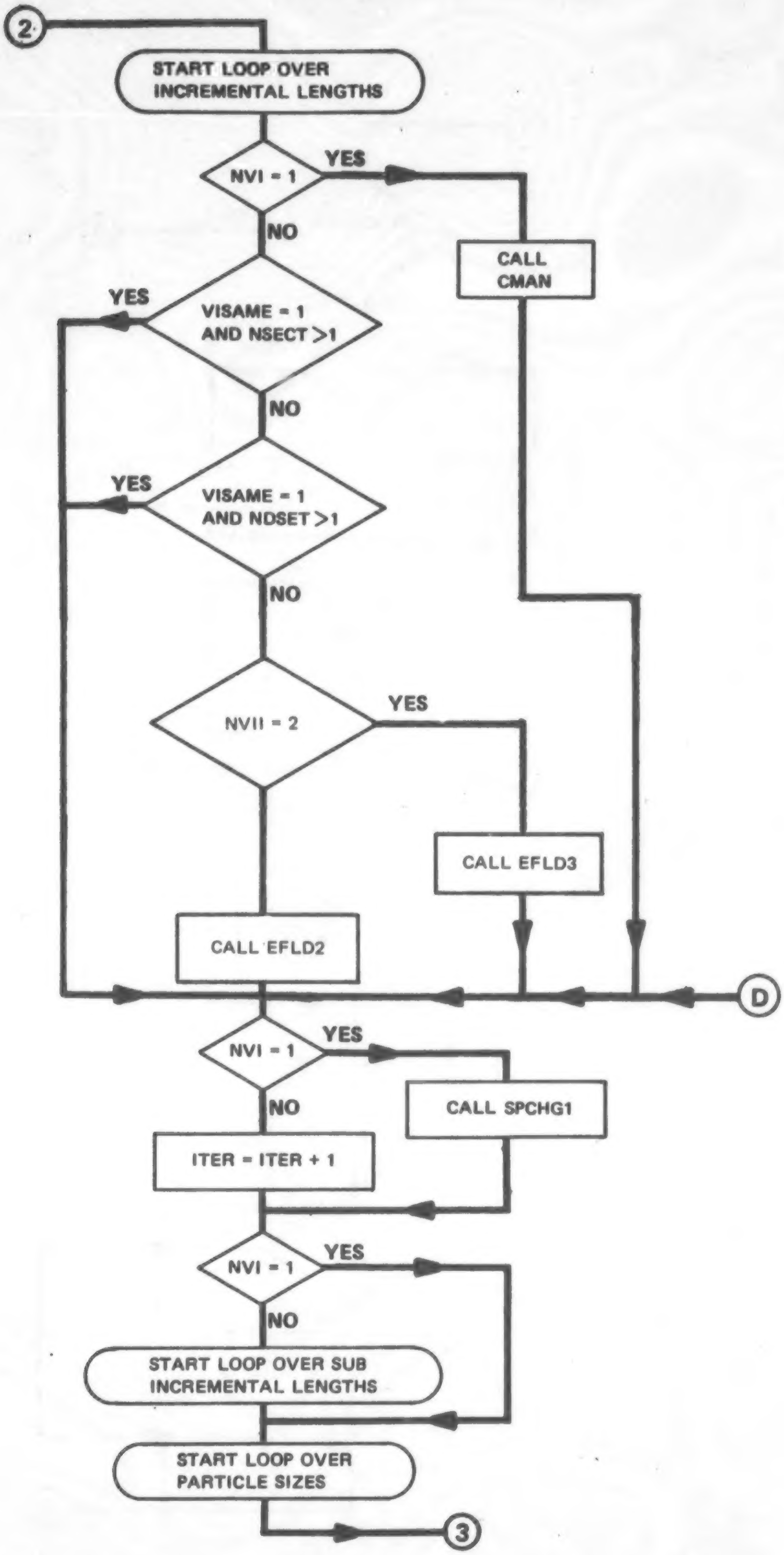

Figure 13. Simplified flow chart for logic of the entire program (sheet 3 of 7).

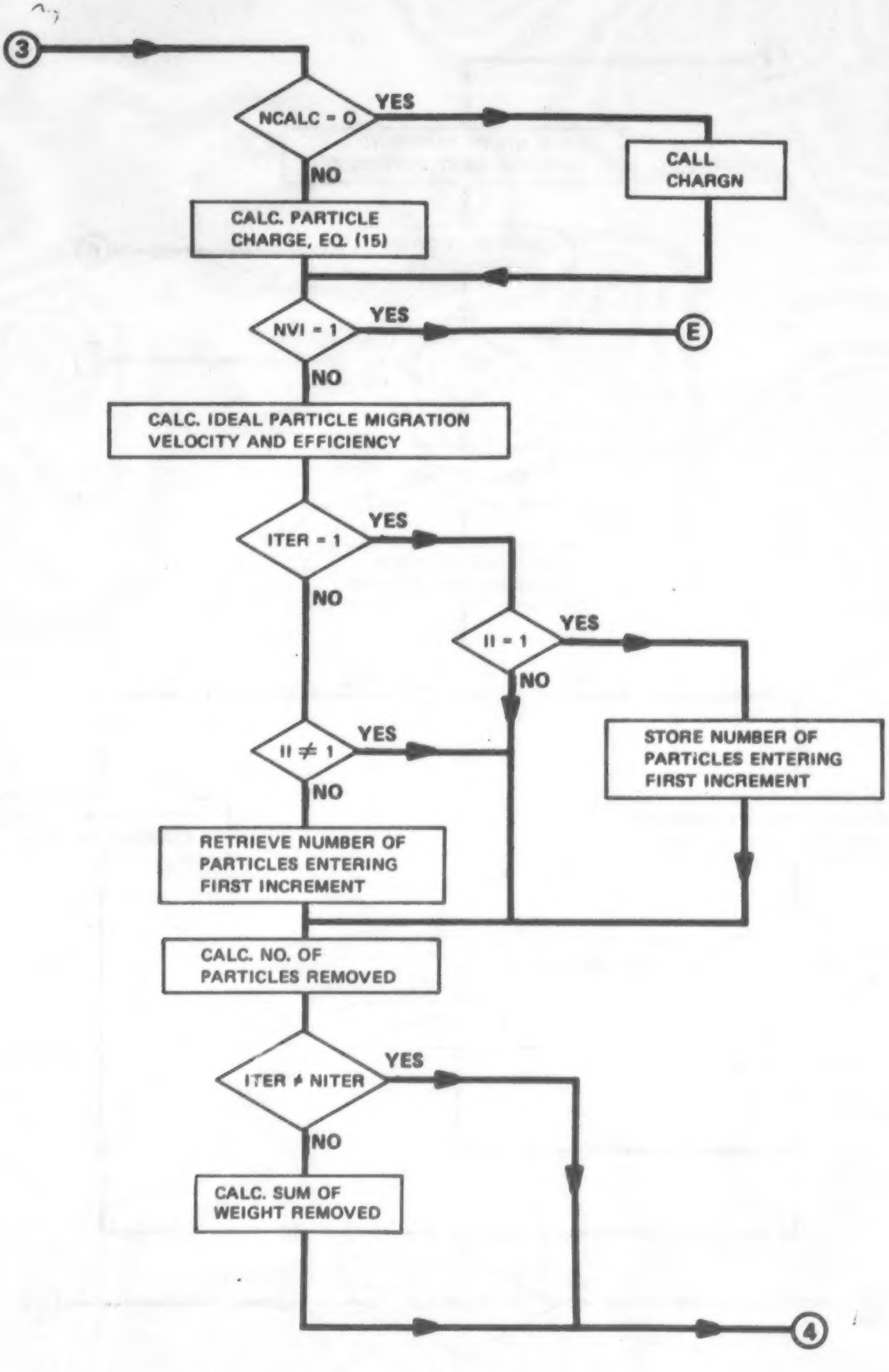
3
NCALC = 0
YES
CALL CHARGN
NO
CALC. PARTICLE CHARGE, EQ. (15)
NVI = 1
YES
E
NO
CALC. IDEAL PARTICLE MIGRATION VELOCITY AND EFFICIENCY
ITER = 1
YES
NO
II = 1
YES
NO
II ≠ 1
YES
NO
STORE NUMBER OF PARTICLES ENTERING FIRST INCREMENT
RETRIEVE NUMBER OF PARTICLES ENTERING FIRST INCREMENT
CALC. NO. OF PARTICLES REMOVED
ITER ≠ NITER
YES
NO
CALC. SUM OF WEIGHT REMOVED
4

Figure 13. Simplified flow chart for logic of the entire program (sheet 4 of 7).

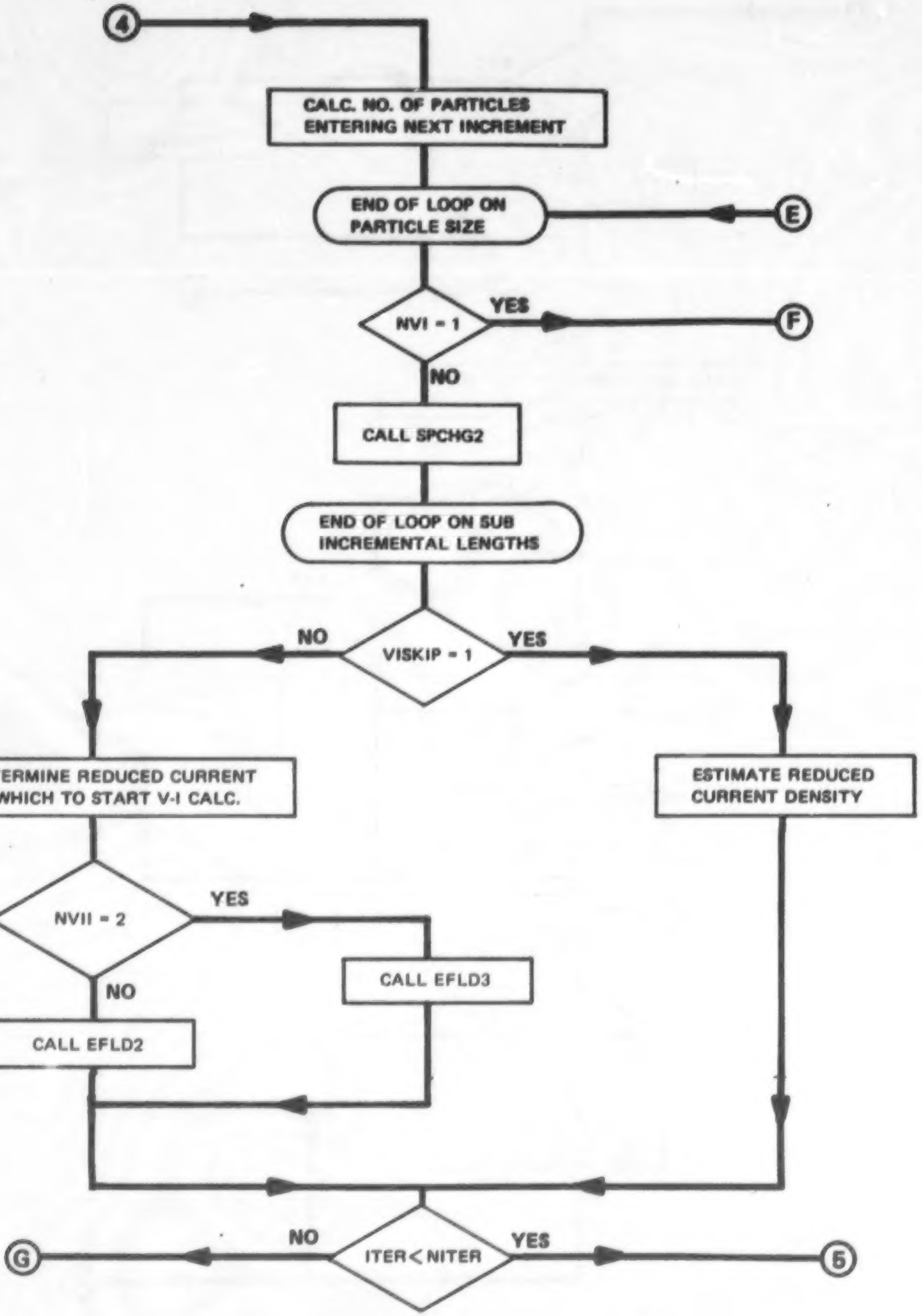
4
CALC. NO. OF PARTICLES ENTERING NEXT INCREMENT
END OF LOOP ON PARTICLE SIZE
E
NVI = 1
YES
F
NO
CALL SPCHG2
END OF LOOP ON SUB INCREMENTAL LENGTHS
NO
VISKIP = 1
YES
DETERMINE REDUCED CURRENT AT WHICH TO START V-I CALC.
ESTIMATE REDUCED CURRENT DENSITY
NVII = 2
YES
CALL EFLD3
NO
CALL EFLD2
G
NO
ITER < NITER
YES
5

Figure 13. Simplified flow chart for logic of the entire program (sheet 5 of 7).

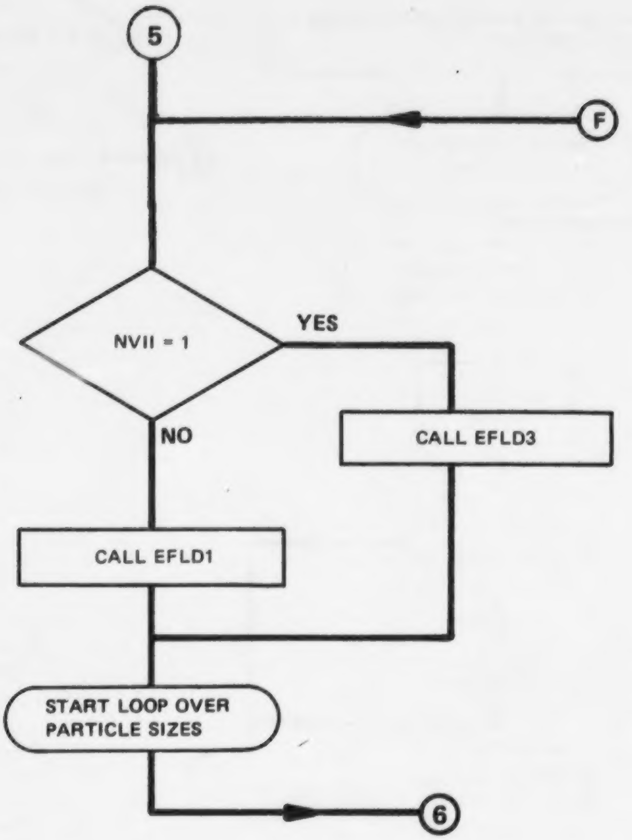

Figure 13. Simplified flow chart for logic of the entire program (sheet 6 of 7).

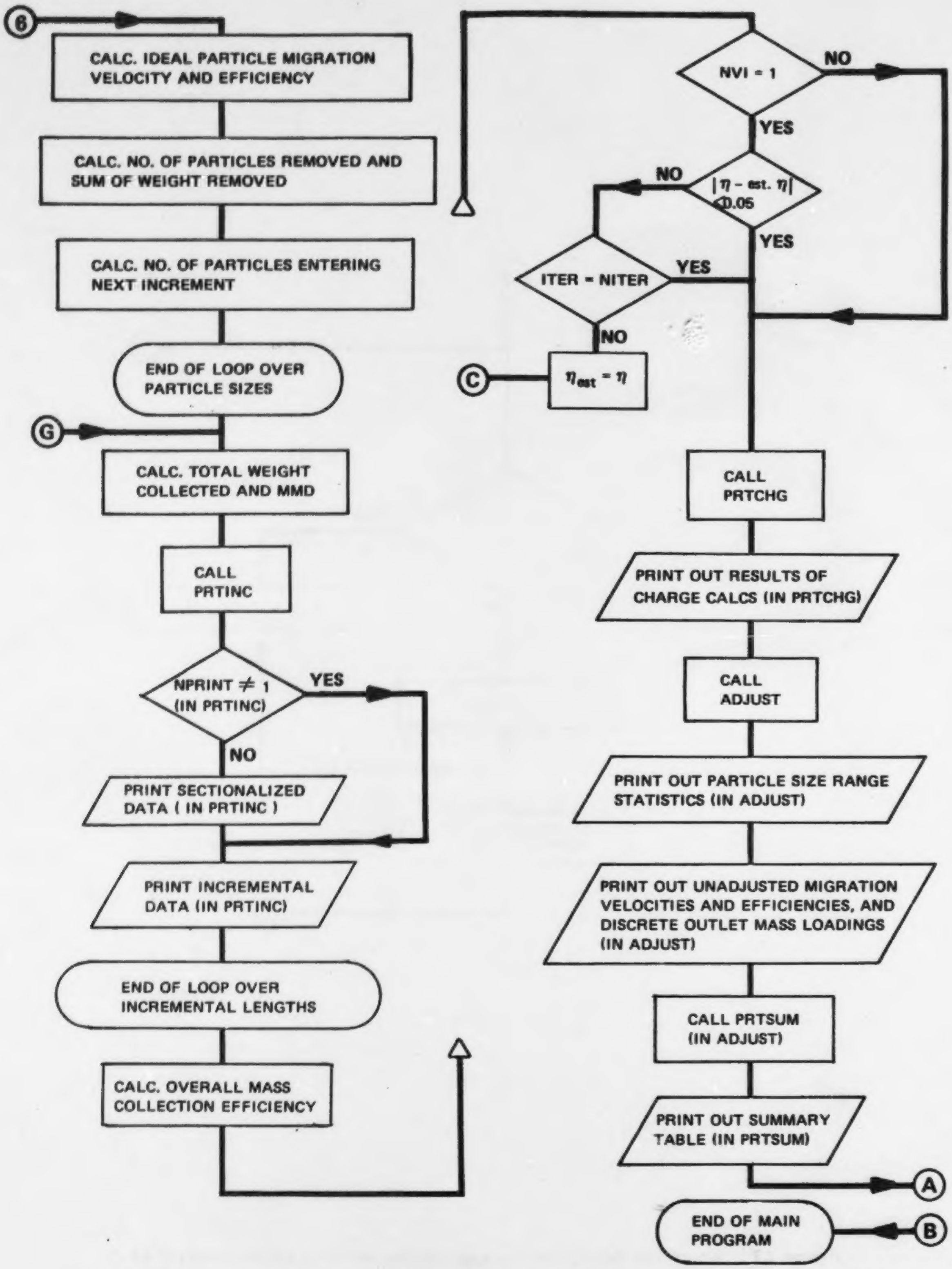
6
CALC. IDEAL PARTICLE MIGRATION VELOCITY AND EFFICIENCY
CALC. NO. OF PARTICLES REMOVED AND SUM OF WEIGHT REMOVED
CALC. NO. OF PARTICLES ENTERING NEXT INCREMENT
END OF LOOP OVER PARTICLE SIZES
G
CALC. TOTAL WEIGHT COLLECTED AND MMD
CALL PRTINC
NPRINT ≠ 1 (IN PRTINC)
YES
NO
PRINT SECTIONALIZED DATA (IN PRTINC)
PRINT INCREMENTAL DATA (IN PRTINC)
END OF LOOP OVER INCREMENTAL LENGTHS
CALC. OVERALL MASS COLLECTION EFFICIENCY
NVI = 1
NO
YES
|η – est. η| < 0.05
NO
YES
ITER = NITER
YES
NO
C
η_est = η
CALL PRTCHG
PRINT OUT RESULTS OF CHARGE CALCS (IN PRTCHG)
CALL ADJUST
PRINT OUT PARTICLE SIZE RANGE STATISTICS (IN ADJUST)
PRINT OUT UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS (IN ADJUST)
CALL PRTSUM (IN ADJUST)
PRINT OUT SUMMARY TABLE (IN PRTSUM)
A
END OF MAIN PROGRAM
B

Figure 13. Simplified flow chart for logic of the entire program (sheet 7 of 7).

It is stressed that one who is not familiar with the model should read both volumes of the previous report[2,3] before trying to use the program to model precipitators. Only the information relevant to the present modifications is discussed in this report.

INPUT DATA

The formats for inputting data to the program are exactly the same as for the previous version of the model. In fact, any set of input data which would execute in the program listed in Revision 1 of the model will also execute in the program listed in this report. The only difference will be that charging is computed using Gaussian Quadratures rather than Simpson's rule.

There is one important extension to the options available in the input parameters. In addition to the values of 1 and 2, the parameter NVI can now have values of 3 and 4 as well. The parameter NVI is an indicator which determines the technique used to compute the electrical conditions. As before, when NVI = 1 the user must supply known or measured values of the operating applied voltage and current. If NVI = 2, the program will construct a voltage-current curve for a specified wire-plate geometry up to a voltage which is specified by the user. Both of these techniques for determining the electrical conditions are discussed in Volume I[2] of the previous report. When NVI has the new values of either 3 or 4, a new parameter NVII is initialized by the program. NVI is then set to either 1 or 2 so that the logic of the program proceeds as before. If NVI = 3, NVII is set to 1 and then NVI is also set to 1. If NVI = 4, NVII is set to 2 and then NVI is also set to 1. If NVII = 1, EFLD3 rather than EFLD1 is called. A calculation completely analogous to that in EFLD1 is performed except that the analytic expressions from Section 4 are used to compute the electrical properties. Under these conditions, the electric field at the surface of the wire is chosen so as to match the specified potential at the wire. In this case, Peek's condition on the field is not used. If NVII = 2, EFLD3 rather than EFLD2 is called. The resulting calculation is completely analogous to that in EFLD2 except that the electrical properties are computed from the analytic expressions described in Section 4. In this case a current-voltage curve is generated up to the operating voltage specified. The reader is referred to Volume 2[3] of the previous report for the details of constructing a complete set of input data. Since the Simpson's rule integration scheme has been replaced by Gaussian Quadratures, the parameter NUMINC is no longer used in the program. It is still read in, however. The output data will be identical to that described in Volume 2[3] of the previous report.

MACHINE-DEPENDENT ASPECTS OF THE COMPUTER PROGRAM

The computer program, presented and discussed in this report, has been developed on a Digital Equipment Corporation (DEC) PDP

15/76 computer. Although the program should compile successfully with only minor changes on most computers with a fortran compiler, there are certain machine-dependent aspects of the program that should be discussed. These machine-dependent properties can be utilized to make the usage of the program more general and to extend the application of the program.

In order to use the program on most computers, the first two executable statements in the program must be changed. These statements define the input (read) and output (write) logical unit numbers. The value of the variable NREAD specifies the input logical unit number and the value of NPRNT specifies the output logical unit number. These two changes should normally be the only modifications which are necessary to allow successful compilation of the program. The approximate time required to compile the entire program on the DEC PDP 15/76 computer was 1716 seconds.

Once the program is compiled, it will execute provided that enough core is available to store the program. The total core requirements on the DEC PDP 15/76 are 131,221 octal words (45,713 decimal words) for the program plus 7,632 octal words (3,994 decimal words) for system software necessary to implement the program. Table 3 lists the various segments of the program and their core requirements.

Due to the fact that the particular DEC PDP 15/76 which has been used to develop the program has only approximately 57,563 octal words (24,435 decimal words) of core that can be accessed at any given time, it was necessary to overlay subroutines in order to fit the program into core. The main program (ESPM), the data Block, and subroutine CMAN were kept in resident core and the overlay was established by setting up the following six links:

LINK1 = SPCHG1, EFLD1

LINK2 = SPCHG2, EFLD2

LINK3 = ADJUST, WADJST, CFIT, LNFIT, QTFE, LNDIST, PRTSUM

LINK4 = CHARGN, RATE, ZERO/ARCCOS

LINK5 = PRTINC, PRTCHG, PRTINP, CHGSUM

LINK6 = EFLD3/ARCCOS

With the above overlay, the required core is 56,275 octal words (23,741 decimal words) including system software. The core requirements were determined by the core utilized in resident core and the largest link (LINK2). Also, the link table required an additional 323 octal words (211 decimal words) of core.

In order to get the program to execute on computers with small storage capacities, an overlay similar to the one discussed

TABLE 3. CORE REQUIREMENTS FOR VARIOUS SEGMENTS OF THE COMPUTER PROGRAM

	Octal Words	Decimal Words
RESIDENT CODE		
ESPM	11,541	4,961
CMAN	1,362	754
DATA	3,411	1,801
BLK1	502	322
BLK2	62	50
BLK3	16	14
BLK4	1	1
BLK5	15	13
BLK6	1,354	748
BLK7	3,410	1,800
BLK8	170	120
BLK9	74	60
BLK10	74	60
BLK11	53	43
BLK12	202	130
BLK13	703	451
BLK14	4	4
BLK15	71	57
BLK16	5	5
BLK17	2	2
BLK18	17	15
BLK19	57	47
BLK20	263	179
BLK21	1,774	1,020
System Software	6,731	3,545
LINK1		
SPCHG1	407	263
EFLD1	13,664	6,068
LINK2		
SPCHG2	732	474
EFLD2	15,775	7,165

	Octal Words	Decimal Words
LINK3		
ADJUST	7,200	3,712
WADJST	610	392
CFIT	372	250
LNFIT	624	404
QTFE	160	112
LNDIST	1,567	887
PRTSUM	1,635	925
System Software	393	267
LINK4		
CHARGN	343	228
RATE	634	412
ARCCOS	200	128
ZERO	130	88
System Software	12	10
LINK5		
PRTINC	1,747	999
PRTCHG	1,563	883
PRTINP	5,352	2,794
CHGSUM	1,156	622
System Software	110	72
LINK6		
EFLD3	14,046	6,182
ARCCOS	200	128

above may be possible. On computers with large memories such as the IBM 370/158, UNIVAC 1100, or CDC 7600, no such action is necessary. When an overlay is not used, a significant amount of core could be gained by deleting subprograms EFLD1 and EFLD2. This might provide additional core for expanding some of the arrays.

Without changing the fundamental operations of the program, the dimensions of certain arrays can be decreased or increased if necessary. The dimensions of these arrays may be decreased in order to fit the program on a small computer or they may be increased to give greater flexibility on a large computer. In the version of the program presented in this report, the following quantities determine array sizes which may be changed:

- number of increments along the length of the precipitator
- number of particle size bands
- number of electrical sections in the direction of gas flow
- number of grid points used in the calculations of electrical conditions
- number of rapping puff particle size distributions
- number of sets of nonideal conditions of nonuniform gas velocity distribution and gas sneakage and/or particle reentrainment without rapping.

The above quantities have maximum values of 45, 20, 10, 225, 10, and 15, respectively.

The number of increments along the length of the precipitator that can be utilized can be changed by changing the dimension of DW and the dimension of the first subscript of XDC. DW appears in COMMON/BLK6/ and XCD appears in COMMON/BLK7/. COMMON/BLK6/ appears in the main program and subroutines PRTINP, CHGSUM, PRTINC, PRTCHG, ADJUST, and PRTSUM. COMMON/BLK7/ appears in the main program and subroutines SPCHG2 and PRTCHG. DW also appears in the dimension statement in the subroutine SPCHG1. If the storage capacity of the computer is large enough, the program should be modified to handle more than 45 increments. Although 120 increments should be sufficient to handle most cases, as many as 180 increments may be necessary in certain cases.

The number of particle size bands that can be utilized can be changed by changing the dimension of CHKSUM, DIAM, ONO, DXS, XMV, PCNT, RAD, CCF, VOL, XNO, Q, WS, QSAT, OLDQ, OLDXNO, XDC, OLDQF, OLDQT, SOLDQF, SOLDQT, YY, RPCNT, DMDLD, WUNCOR, RDMDLD, CDMDLD, PCTOT, CPCTOT, WSL, PXS, EUNCOR, and AREA. In addition, changes must be made to those variables which depend on the number of particle diameters in the particle size histogram. These variables must have a dimension which has a value of 1 greater than those which depend on the number of size bands. These variables include PRCU, ENDPT, PRCUNR, RPRCU, PRCUC, Z, and Y. CHKSUM appears in the dimension statement in the main program. DIAM, ONO, DXS, XMV, PCNT, RAD, CCF, and PRCU appear in COMMON/BLK1/ VOL, XNO, Q, WS, QSAT, OLDQ, and OLDXNO appear in COMMON/BLK6/. XDC appears in COMMON/BLK7/. ENDPT appears in COMMON/BLK11/. OLDQF, OLDQT, SOLDQF, and SOLDQT appear in COMMON/BLK20/. COMMON/ BLK1/ appears in the main program and subroutines PRTINP, PRTCHG, and ADJUST. COMMON/BLK6/ and COMMON/BLK7/ appear in those locations previously designated. COMMON/BLK11/ appears in the main program and subroutines PRTINP, ADJUST, LNFIT, and LNDIST. COMMON/BLK20/ appears in the main program and subroutine CHGSUM. QSAT and XNO appear in the dimension statement in subroutine SPCHG1. XNO, RAD, CCF, OLDQ, and Q appear in the dimension statement in subroutine SPCHG2. YY appears in the dimension statement in subroutine PRTCHG. RPCNT, DMDLD, WUNCOR, RDMDLD, CDMDLD, PCTOT, CPCTOT, WSL, PXS, PRCUNR, RPRCU, PRCUC, and EUNCOR appear in the dimension statement in subroutine ADJUST. DIAM, ONO, and PXS appear in the dimension statement in subroutine WADJST. Z and Y appear in the dimension statement in subroutine CFIT. Z, Y, and PRCU appear in the dimension statement in subroutine LNFIT. AREA, PRCU, and PCNT appear in the dimension statement in subroutine LNDIST. In changing XDC, it is the second subscript which accounts for the maximum number of size bands which can be considered.

The number of electrical sections in the direction of gas flow that can be utilized can be changed by changing the dimension of LSECT, LINCS, PS, AS, VOS, TCS, WLS, ACS, BS, SYS, VGS, VGASS, TEMPS, VISS, RFS, START1, START2, START3, VSTAR, and NWS. LSECT, LINCS, and PS appear in COMMON/BLK2/. AS, VOS, TCS, WLS, ACS, BS, SYS, VGS, VGASS, TEMPS, VISS, RFS, START1, START2, START3, and VSTAR appear in COMMON/BLK6/. NWS appears in COMMON/BLK19. COMMON/BLK2/ appears in the main program and in subroutine PRTINP and ADJUST. COMMON/BLK6/ appears in those locations previously designated. COMMON/BLK19/ appears in the main program and subroutines PRTINP, PRTCHG, and ADJUST. LSECT appears in the dimension statement in subroutine SPCHG1.

The number of grid points that can be utilized in the calculation of electrical conditions can be changed by changing the dimensions of VCOOP, RHO, EX, OLDRO, OLDV, CDNSTY, V, EY, EAVGS, CHFIDS, ECOLLS, EAVG, CHFID, ECX, ECY, X1, Y1, AX, AY, and ECOLL. VCOOP appears in COMMON/BLK13. EAVG and CHFID appear in COMMON/ BLK8/. ECOLL appears in COMMON/BLK9/. ECX, ECY, X1, Y1, AX, and AY appear in COMMON/BLK21/. COMMON/BLK13/ appears in the main program and subroutines CMAN, EFLD1, EFLD2, and EFLD3. COMMON/ BLK8/ appears in the main program and subroutines SPCHG2, EFLD2, EFLD3, and PRTCHG. COMMON/BLK9/ appears in the main program, subroutine EFLD2, and EFLD3. COMMON/BLK21/ appears in EFLD3 and CMAN.

RHO, EX, OLDRO, OLDV, CDNSTY, V, and EY appear in the dimension statement in subroutine EFLD1. RHO, EX, OLDRO, OLDV, CDNSTY, V, EY, EAVGS, CHFIDS, and ECOLLS appear in the dimension statement in subroutines EFLD2 and EFLD3. VCOOP, RHO, EX, OLDRO, OLDV, CDNSTY, V, EY, ECX, and ECY are doubly subscripted variables with the first subscript referring to the number of grid points in the direction perpendicular to the gas flow and the second subscript referring to the number of grid points in the direction parallel to the gas flow. EAVG, CHFID, ECOLL, EAVGS, CHFIDS, and ECOLLS are singly subscripted variables whose dimension must be a value of two less than twice the dimension of the second subscript in the variables VCOOP, RHO, EX, OLDRO, OLDV, CDNSTY, V, and EY.

The number of rapping puff particle size distributions that can be utilized can be changed by changing the dimension of ARD50 and ARSIGM. ARD50 and ARSIGM appear in COMMON/BLK12/. COMMON/BLK12/ appears in the main program and in subroutines PRTINP and ADJUST.

The number of sets of nonideal conditions of nonuniform gas velocity distribution and gas sneakage and/or particle reentrainment without rapping that can be utilized can be changed by changing the dimension of ASNUCK, AZIGGY, and AZNUMS. These variables appear in COMMON/BLK12/. COMMON/BLK12/ appears in those locations previously designated.

If any changes are made that affect arrays, these changes will also affect the limitations on the input data discussed in the previous report. The limitations on the input data discussed previously are only applicable to the version of the program presented in Appendix F of this report. If changes are made, then new limitations on the input data must be established.

EXAMPLE CASES AND COMPARISONS OF THE ANALYTIC APPROXIMATIONS WITH PREDICTIONS OF THE PREVIOUS MODEL

Example 1

In this example, the model calculations are performed using geometrical parameters corresponding to a laboratory precipitator. This device has a plate-to-plate spacing of 25.4 cm, a wire-to-wire spacing of 12.7 cm, a wire radius of 0.1191 cm, a gas velocity of 0.976 m/sec, and a current density at the plate of 25.8 nA/cm^2. These parameters are also typical of full-scale precipitators. The inlet mass loading and particle size distribution, operating voltages and currents, gas flow rate and velocity, and gas temperature and pressure were measured and are used as input data for the model. A reduced effective ion mobility of 1.65 x 10^{-4} m^2/v-sec is used in the model since the use of this value results in good agreement between theoretical and experimental current-voltage characteristics for corona discharge in ambient air. Although the precipitator is divided into four baffled and independent electrical sections, the last two sections were connected together during the experiment and this is reflected in the input data to the model.

Figure 14 shows a comparison of fractional collection efficiencies computed from Revision 1 of the model using electrical conditions measured in a laboratory precipitator with those computed from Revision 2 of the model using the approximate calculation of the electrical properties. Since the predictions of Revision 1 of the model have been previously compared with the experimental results, the experimental values will not be shown. Instead, a comparison of the new calculations obtained using the approximations described in Section 4 with the previous model predictions will be stressed. Revision 2 of the model contains a new charge calculation scheme as well as an approximate representation of the electrical solutions. As can be seen in Figure 14, the fractional collection efficiencies computed by the two versions of the model are in excellent agreement. The maximum difference of three percent occurs for a diameter of 0.25 micrometers. The input data card set which was used in Revision 2 of the model is shown in Table 4. The output data corresponding to the input in Table 4 are given in Appendix G. The corresponding set of output data from Revision 1 of the model are shown in Appendix H. Comparison of these two appendices will show that the overall agreement of the two versions of the model is quite good. The calculations shown in Appendix H required 2,801 seconds on the DEC PDP 15/76 computer while the corresponding calculations shown in Appendix G required only 334 seconds. These results represent a significant saving in computer time without a significant loss in accuracy.

Example 2

In this example, the geometric parameters corresponding to the laboratory precipitator were the same as in Example 1. In this case, the gas velocity was 1.49 m/sec and the average current density at the plate was 10.8 nA/cm^2. The primary difference in this example and the previous one lies in the manner in which the electrical operating conditions were determined. For this case, these quantities are predicted by the model by calculating clean-gas, current-voltage curves for each electrical section and estimating the reduction in current in each increment of length due to charged particles. A reduced effective ion mobility of 1.65 x 10^{-4} m^2/V-sec and a roughness factor of 0.90 were used.

Figure 15 shows a comparison of the fractional collection efficiencies predicted by Revision 1 of the model using integrated electrical solutions with those predicted by Revision 2 of the model using the approximate electrical solutions discussed in Section 4. A maximum difference between the two predictions of three percent occurs at a diameter of 1.6 micrometers. Table 5 gives the input data card set used to obtain the model predictions. The output data set is shown in Appendix I. The corresponding calculations for Revision 1 of the model are shown in Appendix J. The calculations in Appendix J required 47,886 seconds on the DEC PDP 15/76 computer. The calculations in Appendix I required only 5,175 seconds.

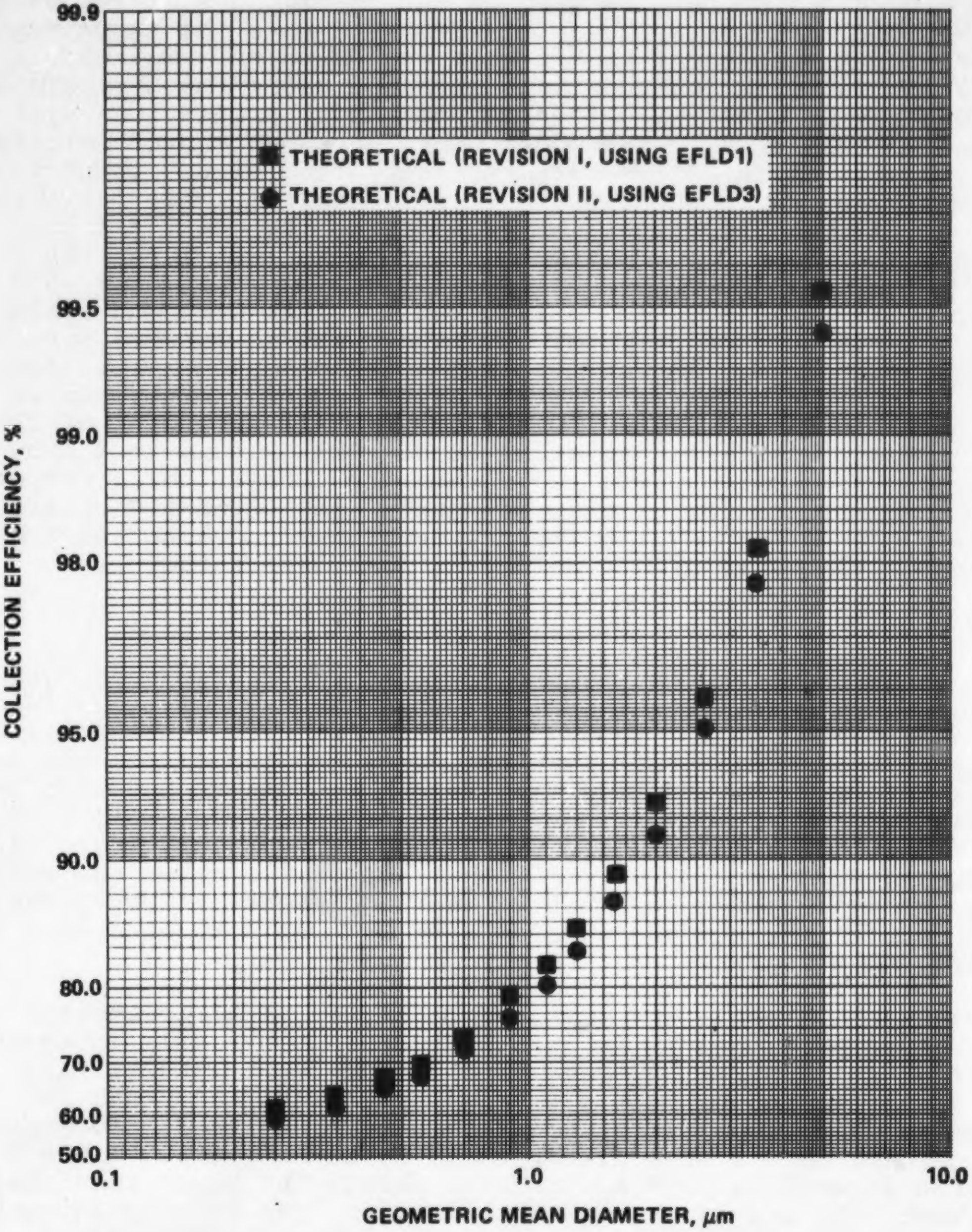

Figure 14. Comparison of fractional collection efficiencies computed from Revision I of the model using electrical conditions measured in a laboratory precipitator with those computed from Revision II of the model using the approximations.

TABLE 4. INPUT DATA CARD SET FOR EXAMPLE 1

```
                                  COLUMN NUMBER
                1         2         3         4         5         6         7         8
CARD   12345678901234567890123456789012345678901234567890123456789012345678901234567890
NUMBER

  1    1601
  2    LAB_ESP:_SCA=125FT2/1000ACFM;J=24.0UA/FT2
  3    0101031010030001010102
  4    0503
  5    0.015___10.0____99.0____1000.0__5.1_____1.03____0.0001651.0_____1500000.1.00E+09
  6    0.000.004.000.100.104.00
  7    0.20____0.30____0.40____0.50____0.60____0.80____1.00____1.20____1.40____1.80
  8    2.20____3.00____4.00____6.00____10.0____20.0
  9    0.0_____0.0002__0.4002__1.0002__2.6672__7.6672__12.6002_17.6002_21.3332_29.3332
 10    36.0002_46.6672_57.3342_68.6672_80.6672_100.0
 11    03030306
 12    +6.2500E+00+4.6000E+04+1.5000E-04+6.2500E+00+4.6875E-02+5.0000E+00+5.0000E+00
 13    +2.5000E+00+2.0000E+02+3.2000E+00+7.6800E+01+1.0000E+00+1.8000E-05+8.3333E-01
 14    +6.2500E+00+4.5800E+04+1.5000E-04+6.2500E+00+4.6875E-02+5.0000E+00+5.0000E+00
 15    +2.5000E+00+2.0000E+02+3.2000E+00+7.6800E+01+1.0000E+00+1.8000E-05+8.3333E-01
 16    +1.2500E+01+4.4400E+04+3.0000E-04+1.2500E+01+4.6875E-02+5.0000E+00+1.0000E+01
 17    +2.5000E+00+2.0000E+02+3.2000E+00+7.6800E+01+1.0000E+00+1.8000E-05+8.3333E-01
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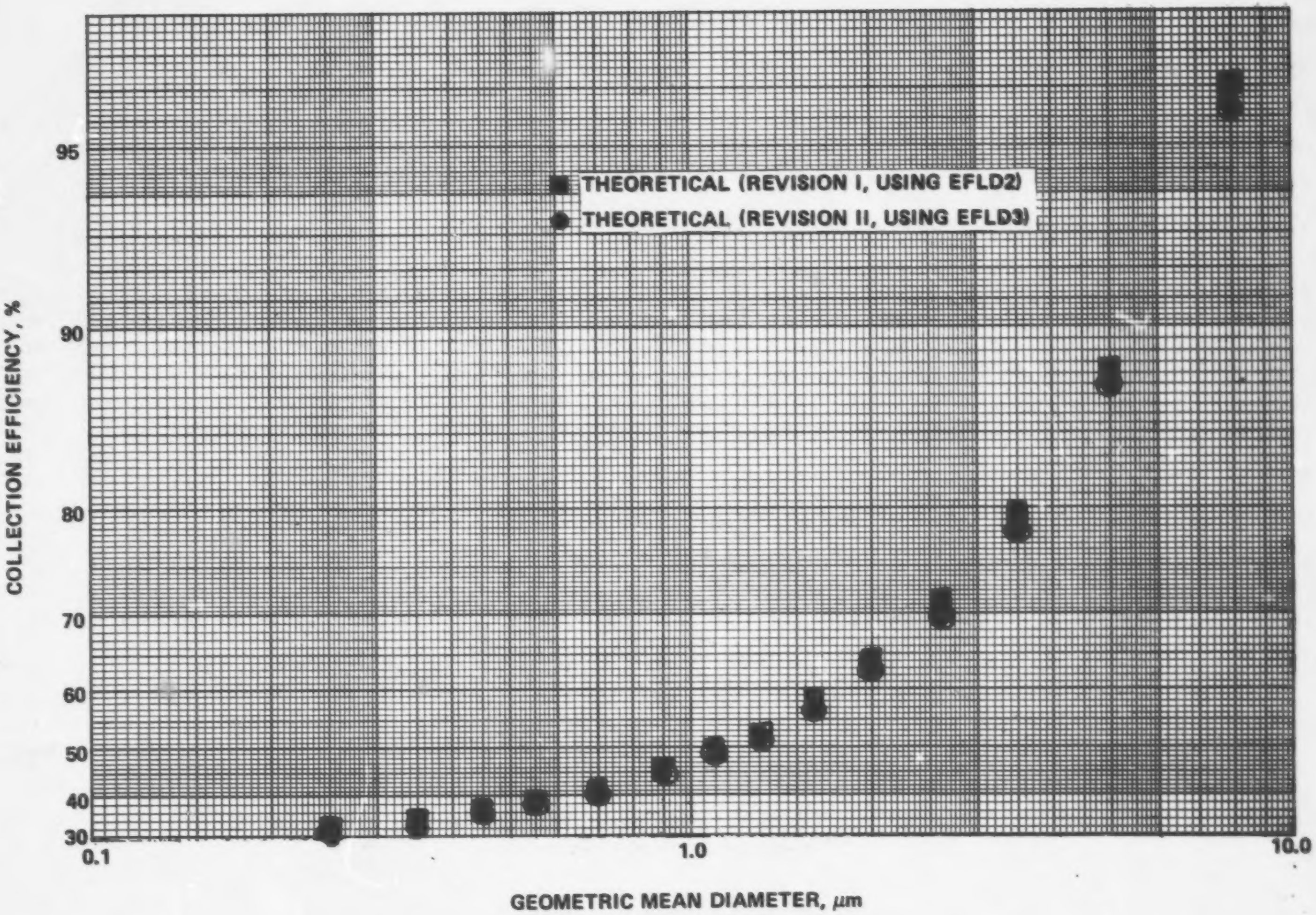

Figure 15. *Comparison of fractional collection efficiencies computed from Revision I of the model using theoretical current-voltage calculations with those computed from Revision II of the model using the approximate electrical calculations.*

TABLE 5. INPUT DATA CARD SET FOR EXAMPLE 2

```
                                  COLUMN NUMBER
                 1         2         3         4         5         6         7         8
        12345678901234567890123456789012345678901234567890123456789012345678901234567890
CARD
NUMBER

  1     1601
  2     LAB_ESP:_SCA=82FT2/1000ACFM;CALCULATED_V-I_FOR_EACH_ELECTRICAL_SECTION
  3     01010415150100010101 02
  4     0503
  5     2002210102
  6     0.065___10.0____99.0____1000.0__5.1_____1.03____0.0001651.0_____1500000.1.00E+09
  7     0.000.004.000.100.104.00
  8     0.20____0.30____0.40____0.50____0.60____0.80____1.00____1.20____1.40____1.80
  9     2.20____3.0_____4.0_____6.0_____10.0____20.0
 10     0.0_____0.0076__0.0563__0.2682__0.8652__2.9845__5.9695__9.5515__12.835__19.7004
 11     26.8643_38.8042_49.2516_64.1765_79.1014_100.0
 12     03060612
 13     +6.2500E+00+4.0800E+04+6.2500E-05+6.2500E+00+4.6875E-02+5.0000E+00+5.0000E+00
 14     +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 15     +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
 16     +6.2500E+00+4.0800E+04+6.2500E-05+6.2500E+00+4.6875E-02+5.0000E+00+5.0000E+00
 17     +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 18     +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
 19     +1.2500E+01+3.9600E+04+1.2500E-04+1.2500E+01+4.6875E-02+5.0000E+00+1.0000E+01
 20     +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 21     +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
```

Example 3

This example used the same input data as Example 2 except that the estimation procedure described in Volume I[2] of Revision 1 of the model report was employed. In this application of the estimation procedure, an I-V curve is generated to yield the operating values of current and voltage. The input data card set used in Revision 2 of the model is given in Table 6. The output data from the calculation is given in Appendix K. Since the results of the calculation using the estimation with this set of parameters was not presented in Revision 1 of the model report, the input data card set for this case is shown in Table 7. The corresponding output data are shown in Appendix L. Figure 16 shows a comparison of the fractional collection efficiencies from the two calculations. Once again there is good agreement between the two model calculations. A maximum difference in collection efficiency of three percent occurs at a diameter of about 1.3 micrometers. The time required by the DEC PDP 15/76 computer to perform the calculations shown in Appendix K was 2,568 seconds. The corresponding time required for the calculations shown in Appendix L was 10,019 seconds. These two times can be contrasted with those in Example 2 for which the more rigorous calculations took 5,175 seconds and 47,886 seconds, respectively. For a comparison of the estimation procedure with the more rigorous calculation, one should use Appendices L and J. However, it can be seen from Appendices K and I that the approximations contained in Revision 2 of the model give an adequate representation of the theory with a substantial savings in time of computation.

Example 4

In this example, the two versions of the model are compared using parameters measured at a full-scale, cold-side precipitator. Predictions of the model were compared with the experimental measurements in the previous model report. The input data card set is shown in Table 8. The output data for this calculation using the approximate electrical solutions are shown in Appendix M. The output data for the corresponding calculations using integrated electrical solutions are shown in Appendix N. In these two calculations measured values of current and voltage are used. Figure 17 shows a comparison of the fractional collection efficiencies for these two computations. The maximum difference in computed efficiencies of 1.3 percent occurs for a diameter of 0.2 micrometers. The calculations shown in Appendix N required 6,181 seconds of computer time on the DEC PDP 15/76 system. The calculations shown in Appendix M required only 789 seconds on the same system.

All the comparisons of collection efficiency made here used the ideal cases. In the case of full-scale precipitators, these predictions would not be expected to agree well with measurements. For such cases, nonideal effects described in Revision 1 of the model report would need to be taken into account. Some examples were described in detail in Volume II[3] of the previous model

TABLE 6. INPUT DATA CARD SET FOR EXAMPLE 3 (REVISION 2)

```
                                          COLUMN NUMBER
                  1         2         3         4         5         6         7         8
         12345678901234567890123456789012345678901234567890123456789012345678901234567890
CARD
NUMBER

  1      1601
  2      LAB_ESP:_SCA=82FT2/1000ACFM;CALCULATED_V-I_FOR_EACH_ELECTRICAL_SECTION
  3      0201041515010001010102
  4      0503
  5      2002210102
  6      0.065___10.0____99.0____1000.0__5.1_____1.03____0.0001651.0_____1500000.1.00E+09
  7      0.000.004.000.100.104.00
  8      0.20____0.30____0.40____0.50____0.60____0.80____1.00____1.20____1.40____1.80
  9      2.20____3.0_____4.0_____6.0_____10.0____20.0
 10      0.0_____0.0076__0.0563__0.2682__0.8652__2.9845__5.9695__9.5515__12.835__19.7004
 11      26.8643_38.8042_49.2516_64.1765_79.1014_100.0
 12      03060612
 13      +6.2500E+00+4.0800E+04+6.2500E-05+6.2500E+00+4.6875E-02+5.0000E+00+5.0000E+00
 14      +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 15      +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
 16      +6.2500E+00+4.0800E+04+6.2500E-05+6.2500E+00+4.6875E-02+5.0000E+00+5.0000E+00
 17      +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 18      +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
 19      +1.2500E+01+3.9600E+04+1.2500E-04+1.2500E+01+4.6875E-02+5.0000E+00+1.0000E+01
 20      +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 21      +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
```

TABLE 7. INPUT DATA CARD SET FOR EXAMPLE 3 (REVISION 1)

```
                                       COLUMN NUMBER
                 1         2         3         4         5         6         7         8
CARD    12345678901234567890123456789012345678901234567890123456789012345678901234567890
NUMBER

  1     1601
  2     LAB_ESP:_SCA=82FT2/1000ACFM;CALCULATED_V-I_FOR_EACH_ELECTRICAL_SECTION
  3     0201021515010001010102
  4     1020
  5     2002210102
  6     0.065___10.0____99.0____1000.0__5.1_____1.03____0.0001651.0_____1500000.1.00E+09
  7     0.000.004.000.100.104.00
  8     0.20____0.30____0.40____0.50____0.60____0.80____1.00____1.20____1.40____1.80
  9     2.20____3.0_____4.0_____6.0_____10.0____20.0
 10     0.0_____0.0076__0.0563__0.2682__0.8652__2.9845__5.9695__9.5515__12.835__19.7004
 11     26.8643_38.8042_49.2516_64.1765_79.1014_100.0
 12     03060612
 13     +6.2500E+00+4.0800E+04+6.2500E-05+6.2500E+00+4.6875E-02+5.0000E+00+5.0000E+00
 14     +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 15     +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
 16     +6.2500E+00+4.0800E+04+6.2500E-05+6.2500E+00+4.6875E-02+5.0000E+00+5.0000E+00
 17     +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 18     +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
 19     +1.2500E+01+3.9600E+04+1.2500E-04+1.2500E+01+4.6875E-02+5.0000E+00+1.0000E+01
 20     +2.5000E+00+3.0533E+02+4.8853E+00+7.6000E+01+1.0000E+00+1.8000E-05+4.1667E-01
 21     +9.0000E-01+6.0000E-05+2.0000E-05+2.0000E-05+3.8000E+04
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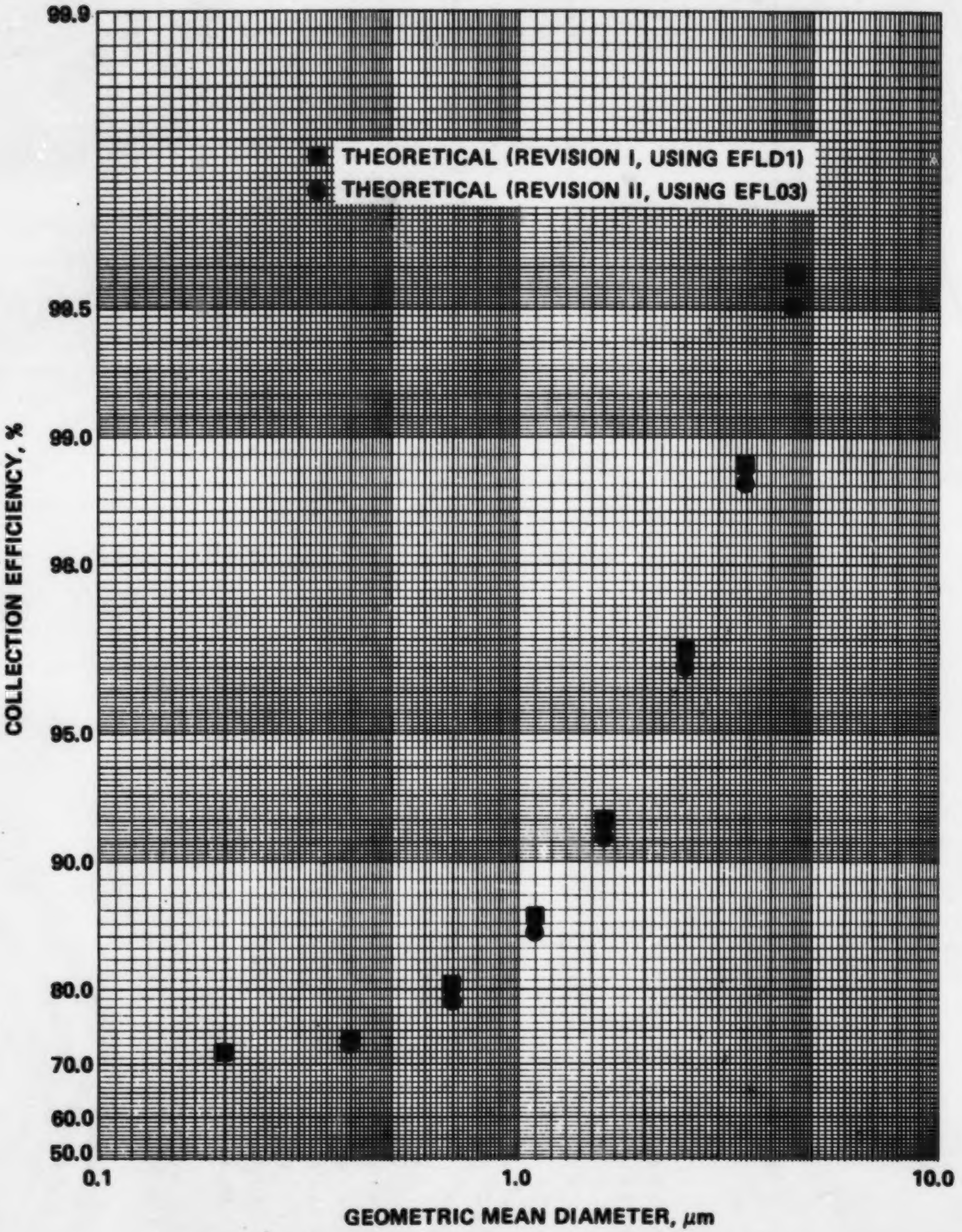

Figure 16. Comparison of fractional collection efficiencies computed from Revision I of the model using the estimation procedure and the parameters in example 2 with the corresponding calculations in Revision II using the approximations.

TABLE 8. INPUT DATA CARD SET FOR EXAMPLE 4

```
                              COLUMN NUMBER
               1         2         3         4         5         6         7         8
CARD  12345678901234567890123456789012345678901234567890123456789012345678901234567890
NUMBER

 1    1401
 2    FULL-SCALE,COLD-SIDE_ESP:_PLANT_A;_SCA=243FT2/1000ACFM;J=15.9UA/FT2
 3    0101031010030001010102
 4    0503
 5    1.966___27.0____99.6____2270.0__100.0___1.2_____0.00022_1.0_____1500000.5.00E+10
 6    0.800.003.000.100.253.00
 7    0.10____0.30____0.50____0.90____1.30____1.90____3.10____3.90____5.10____6.90
 8    10.10___14.90___25.10___29.90
 9    0.0_____0.033___0.286___1.189___2.004___3.524___7.048___8.70____10.352__12.334
10    15.638__20.484__32.599__100.0
11    03101010
12    +2.6460E+04+4.0600E+04+2.7300E-01+1.5720E+04+8.2500E-02+5.5000E+00+1.2000E+01
13    +3.6250E+00+3.2724E+05+4.1000E+00+3.1500E+02+1.0000E+00+2.2900E-05+9.0000E-01
14    +2.6460E+04+4.2100E+04+4.3300E-01+1.5720E+04+8.2500E-02+5.5000E+00+1.2000E+01
15    +3.6250E+00+3.2724E+05+4.1000E+00+3.1500E+02+1.0000E+00+2.2900E-05+9.0000E-01
16    +2.6460E+04+4.2450E+04+5.5800E-01+1.5720E+04+8.2500E-02+5.5000E+00+1.2000E+01
17    +3.6250E+00+3.2724E+05+4.1000E+00+3.1500E+02+1.0000E+00+2.2900E-05+9.0000E-01
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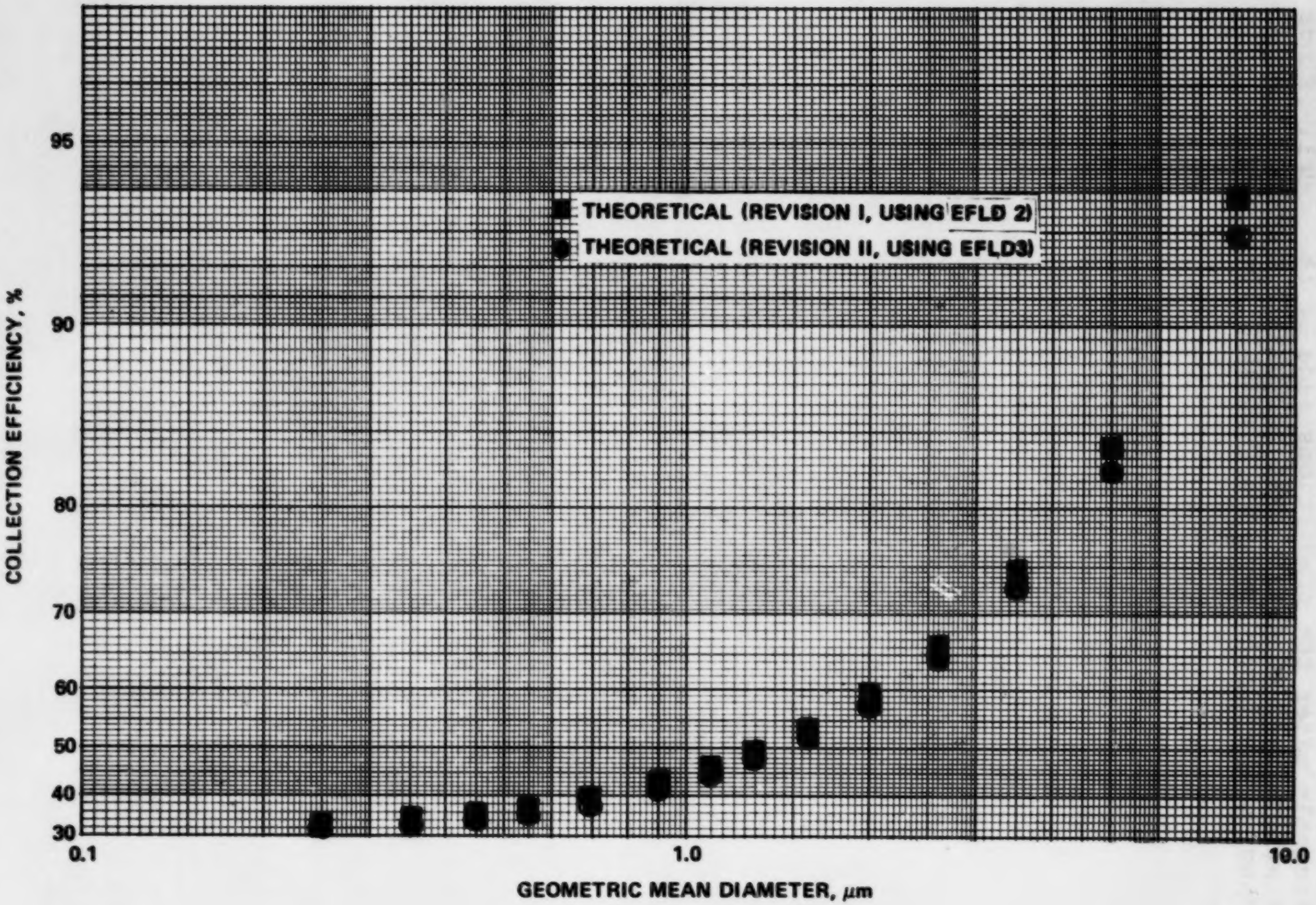

Figure 17. *Comparison of fractional collection efficiencies computed from Revision I of the model using measured electrical conditions from a full-scale, cold-side precipitator with those computed from Revision II of the model using the approximations.*

report. The purpose of the comparisons made here is to establish that the modifications to the model described in this report do not significantly alter the predictions made by the model. Since the modifications lead to significant savings in computer time without changing the final results appreciably their use is justified.

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APPENDIX A

LISTING OF EFLD3

```
      SUBROUTINE EFLD3 (UEQ,AC.VO,SX.SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINAL.VSTART,VW,ACONTY,NWIRE,NEC,EBO,JI1,JI2)
C  EVALUATION OF FIELDS, SPACE CHARGE DENSITY, POTENTIAL , AND
C  CURRENT DENSITY FOR A WIRE-PLATE PRECIPITATOR
      REAL NWIRE,MAXS,MOBILT(15,15)
      LOGICAL LTEST
      DIMENSION RHO(15,15),EX(15,15).OLDRO(15,15),OLDV(15,15),
     1CDNSTY(15,15),V(15,15),EY(15,15),EAVGS(30),CHFIDS(30),ECOLLS(30)
      COMMON/BLK8/EAVG(30),CHFID(30)
      COMMON/BLK9/ECOLL(30)
      COMMON /BLK13/VCOOP(15,15),NVIT
      COMMON/BLK17/NREAD,NPRNT
      COMMON/BLK21/ECX(15,15),ECY(15.15),X1(15),Y1(15),AX(15),AY(15)
      COMMON /BLK22/ LTEST,RHO,V,EX,EY
      DATA OLDRO/225*0./,OLDV/225*0./,CDNSTY/225*0./,MOBILT/225*0./
      COSH(Z)=(EXP(Z)+EXP(-Z))/2.
      SINH(Z)=(EXP(Z)-EXP(-Z))/2.
      VO=-1.*VO
      VW=-1.*VSTART
      RO=AC
      RELD=(293./TDK)*(P/1.)
      ROC=100.*RO
      EBRO=ROC*RF*(30.*RELD+9.*SQRT(RELD/ROC))*1.E+03
      DO 550 I=1,NX
      DO 550 J=1,NY
      MOBILT(I,J)=UEQ
  550 CONTINUE
      PI=3.1416
      EPSO=8.854E-12
      SSTART=START
      MAXS=0.
      NX1=NX-1
      NY1=NY-1
      R=0.975
      IVCK=0
      RC=AC
      DO 1001 II=1,IFINAL
      IF(II.EQ.JI1) START=DSTART
      IF(II.GE.JI2) START=CSTART
      MAXS=MAXS+START
 1526 CONTINUE
      IF((.NOT.LTEST).AND.(NVII.EQ.2))ACONTY=MAXS
      A1=PI/2./SX
      B1=2.*ACONTY/EPSO/MOBILT(NX1,1)
      B1R=SQRT(ABS(B1))
      C1=B1*SY/PI
      R1=R*SY
      VWIR=0.
      EXWIR=0.
      EYWIR=0.
      E1=0.
      E2=0.
      E3=0.
      F1=0.
      F2=0.
      NW=NWIRE
      SUM1=0.
      SIG1=0.
      DO 3601 I=1,NW
      RM=I
      CH=COSH(RM*PI*SY/SX)
      SIG1=SIG1+CH/(CH*CH-COS(A1*AC)*COS(A1*AC))
      SUM1=SUM1+ALOG(ABS((CH-COS(A1*AC))/(CH+COS(A1*AC))))
 3601 CONTINUE
      SUMW=2.*SUM1
      POT1=1./(1./SIN(A1*AC)/SIN(A1*AC)+2.*SIG1)
      SUM1=2.*SUM1+ALOG(ABS((1.-COS(A1*AC))/(1.+COS(A1*AC))))
      IF(R1.GT.SX)R1=SX
      SQON=R1*R1+4.*SX*(SX-R1)
      SQOP=R1*R1+4.*SX*(SX+R1)
      RNN=R1*(2.*SX-R1)
      RNP=R1*(2.*SX+R1)
      ARGR=PI*R1/SX/2.
      FAC1=1.
      IF(R1.LE.SY) GO TO 60
      CALL ARCCOS(SY,R1,ACOS)
      DUM=-ACOS+SY*SQRT(ABS(R1*R1-SY*SY))/R1/R1
      FAC1=(1.+2.*DUM/PI)
      ICOUNT=0
   60 CONTINUE
      EO=EORO/AC
      RLAM=SX*EO*POT1*SUM1/PI/SIN(A1*AC)
      RAD=SQRT(ABS(1.-C1/EO/EO))
      RASX=SQRT(ABS(1.+C1*(SX*SX-AC*AC)/EORO/EORO))
      RAR1=SQRT(ABS(1.+C1*(R1*R1-AC*AC)/EORO/EORO))
      RONSP=R1/(2.*B1*SY/PI/EORO/RAR1+(RAR1-1.)*EORO*(1./SQON+1./SQOP))
     1/(2.*R1*SY/PI/EORO/RAR1+(RAR1-1.)*EORO*(1./SQON+1./SQOP))
      CLAM=EORO*SX*SIN(PI*R1/2./SX)*(2.+R1*(2.*SX-R1)/(R1*R1
     1+4.*SX*(SX-R1))-R1*(2.*SX+R1)/(R1*R1+4.*SX*(SX+R1)))/PI/R1/2.
     2  *(RAR1-1.)
      WLAM=CLAM*FAC1
      VNAUT=CLAM*ALOG(ABS((1.-COS(A1*R1))/(1.+COS(A1*R1))))
     1 -2.*R1R*(SX-R1)*SQRT(ABS(SX-R1))/3.
      VT=VNAUT-EORO*(RAR1-1.   +(RAD-1.)*ALOG(R1/AC)+RAD*ALOG((RAD+1.)/
     1 (RAD+RAR1))+.25*(RAR1-1.)*(ALOG(ABS((AC*AC+4.*SX*(SX-AC))/SQON))
     2 +ALOG(ABS((AC*AC+4.*SX*(SX+AC))/SQOP))))+RLAM+WLAM*SUMW
      IF(NVIT.EQ.1)GO TO 10
      GO TO 30
   10 CONTINUE
      F=VT-VO
      IF(F.EQ.0.)GO TO 30
      IF(ABS(F).LT.1.0E-04*ABS(VO)) GO TO 30
      E3=EORO+0.10*EORO*F/ABS(F)
      IF(F.LT.0.)F1=F
      IF(F.LT.0.)E1=EORO
      IF(F.GT.0.)F2=F
      IF(F.GT.0.)E2=EORO
      IF(F1*F2.LT.0.)E3=(E1*F2-E2*F1)/(F2-F1)
      EORO=E3
      ICOUNT=ICOUNT+1
      IF(ICOUNT.EQ.100)WRITE(NPRNT,  31)
   31 FORMAT(10X,'THE APPLIED POTENTIAL COULD NOT BE MATCHED IN
     1 '100 ITERATIONS'/)
      IF(ICOUNT.GT.100)GO TO 30
      GO TO 60
   30 CONTINUE
      V(1,1)=VT
      CALL CHAN(RLAM,NX,NY,SX,SY,PI,AC,NWIRE)
      X=0.
      DO 3100 I11=1,NX
      IF(NVII.EQ.1)I11=NX
      Y=0.
      DO 3800 I12=1,NY
      IF(LTEST)X=X1(I11)
      IF(LTEST)Y=Y1(I12)
      IF(NVII.EQ.1)X=SX
      X1(I11)=X
      Y1(I12)=Y
      B1=2.*ACONTY/EPSO/MOBILT(I11,I12)
      B1R=SQRT(ABS(B1))
      C1=B1*SY/PI
      IF((I11.EQ.1).AND.(I12.EQ.1))X=AC
      SQRN=SQON+Y*Y
      SQRP=SQOP+Y*Y
      SQXN=X*X+Y*Y+4.*SX*(SX-X)
      SQXP=X*X+Y*Y+4.*SX*(SX+X)
      ARGX=PI*X/SX/2.
      ARGY=PI*Y/SX/2.
      RAXY=SQRT(ABS(1.+C1*(X*X+Y*Y-AC*AC)/EORO/EORO))
      RASXY=SQRT(ABS(1.+C1*(SX*SX+Y*Y-AC*AC)/EORO/EORO))
      RAR1Y=SQRT(ABS(1.+C1*(R1*R1+Y*Y-AC*AC)/EORO/EORO))
      COSHY=COSH(A1*Y)
      SINHY=SINH(A1*Y)
      CX=COS(A1*X)
      IF(X.GT.1.00001 *R1) GO TO 3860
      VXYJ=-EORO*(RAR1Y-RAXY+(RAD-1.)*ALOG(SQRT(ABS((R1*R1+Y*Y)/
     1(X*X+Y*Y))))+RAD*ALOG(ABS((RAD+RAXY)/(RAD+RAR1Y)))+(RAR1Y-1.)*
     2 (ALOG(ABS(SQXN/SQRN))+ALOG(ABS(SQXP/SQRP)))/4.)+VNAUT
      EXJ=-EORO*((RAXY-1.)*X/(X*X+Y*Y)-(RAR1 -1.)*((X-2.*SX)/SQXN
     1 +(X+2.*SX)/SQXP)/2.)
      EYJ=-EORO*((RAXY -1.)*Y/(X*X+Y*Y)-(RAR1Y-1.)*Y/(R1*R1+Y*Y)
     1 -(RAR1 -1.)*(Y/SQXN+Y/SQXP-Y/SQRN-Y/SQRP)/2.)
      RHOJ=-EPSO*C1/EORO/RAXY
     1  *1./(1.+((Y+1.E-09)/SY)**9*2.20)/(1.+.162*Y/SY)
     2 -EPSO*EORO*(RAXY-1.)/2.*((SQON-Y*Y)/SQRN/SQRN+(SQOP-Y*Y)/
     3   SQRP/SQRP)*0.9
      GO TO 3861
 3860 CONTINUE
      VXYJ=CLAM*ALOG(ABS((COSHY-CX)/(COSHY+CX)))
     1+2.*B1R*((X-R1)*SQRT(ABS(X-R1))-(SX-R1)*SQRT(ABS(SX-R1)))/3.
      EXJ=-CLAM*PI*SIN(A1*X)*COSHY/SX/(COSHY*COSHY-CX*CX)
     1 -B1R*SQRT(ABS(X-R1))
      EYJ=-CLAM*PI*CX*SINHY/SX/(COSHY*COSHY-CX*CX)
      RHOJ=-EPSO*B1R/2./SQRT(ABS(X-R1+RONSP))
     1  *1./(1.+((Y+1.E-09)/SY)**9*2.33)/(1.+0.75*Y/SY)
 3861 CONTINUE
      SUMV=0.
      SUMEX=0.
      SUMEY=0.
      COSX=COS(PI*X/2./SX)
      SINX=SIN(PI*X/2./SX)
      DO 100 I=1,NW
      RI=I
      COSHN=COSH(PI*(Y-2.*RI*SY)/2./SX)
      COSHP=COSH(PI*(Y+2.*RI*SY)/2./SX)
      SINHN=SINH(PI*(Y-2.*RI*SY)/2./SX)
      SINHP=SINH(PI*(Y+2.*RI*SY)/2./SX)
      DENON=COSHN*COSHN-COSX*COSX
      DENOP=COSHP*COSHP-COSX*COSX
      TERMV=ALOG(ABS((COSHN-COSX)/(COSHN+COSX)))
     1 +ALOG(ABS((COSHP-COSX)/(COSHP+COSX)))
      SUMV=SUMV+TERMV
      TEREX=COSHN/DENON+COSHP/DENOP
      SUMEX=SUMEX+TEREX
      TEREY=SINHN/DENON+SINHP/DENOP
      SUMEY=SUMEY+TEREY
  100 CONTINUE
      VWIR=WLAM*SUMV
      EXWIR=-PI*WLAM*SINX*SUMEX/SX
      EYWIR=-PI*WLAM*COSX*SUMEY/SX
      VXYJ=VXYJ+VWIR
      EXJ=EXJ+EXWIR
      EYJ=EYJ+EYWIR
      V(I11,I12)=VXYJ+VCOOP(I11,I12)
      EX(I11,I12)=EXJ+ECX(I11,I12)
      EY(I11,I12)=EYJ+ECY(I11,I12)
      RHO(I11,I12)=RHOJ
      IF((I11.EQ.1).AND.(I12.EQ.1))X=0.
      Y=Y+SY/FLOAT(NY1)
 3800 CONTINUE
      X=X+SX/FLOAT(NX1)
 3100 CONTINUE
 3150 CONTINUE
      VW=V(1,1)
      EPLT=0.
      DO 1200 J=2,NY
      IF(LTEST)EPLT=EPLT+(EX(NX,J)+EX(NX,J-1))*AY(J-1)/2.
      IF(.NOT.LTEST) EPLT=
     1      EPLT+(EX(NX,J)+EX(NX,J-1))*SY/FLOAT(NX1)/2.
 1200 CONTINUE
      AEPLT=EPLT/SY
      IF(NVII.EQ.2)WRITE(NPRNT,8888) VW,ACDNTY,AEPLT
 8888 FORMAT(38X,'VW = ',1PE11.4,2X,'ACDNTY = ',1PE11.4,2X,'AEPLT = ',1P
     1E11.4//)
      IF(ABS(EX(NX,1)).LT.EBD) GO TO 1480
      WRITE(NPRNT,1481) VW,ACDNTY
 1481 FORMAT(' THE BREAKDOWN FIELD NEAR THE PLATE IS EXCEEDED AT VW =',E
     111.4,1X,'AND ACDNTY =',E11.4)
      GO TO 1525
 1480 CONTINUE
      IF(IVCK.EQ.1) GO TO 1525
      IF(ABS(VW).EQ.ABS(VO)) GO TO 1525
      IF(ABS(VW).GT.ABS(VO)) GO TO 1523
      OLDVW=VW
      OLDCD=ACDNTY
      GO TO 1524
 1523 CONTINUE
      MAXS=ACDNTY-((ACDNTY-OLDCD)/(VW-OLDVW))*(VW-VO)
      VW=OLDVW
      IVCK=1
      GO TO 1526
 1524 CONTINUE
 1001 CONTINUE
 1525 CONTINUE
      IF(NFC.NE.0) GO TO 3000
      K=1
      DO 3001 J=1,NY1
      RSUM=0.
      ESUM=0.
      DO 3002 I=1,NX
      IF(J.EQ.1) GO TO 3005
      ESUM=ESUM+(SQRT(EX(I,J)**2+EY(I,J)**2)+SQRT(EX(I,J+1)**2+
     1EY(I,J+1)**2))/(2.*NX)
      GO TO 3006
 3005 CONTINUE
      ESUM=ESUM+SQRT(EX(I,J+1)**2+EY(I,J+1)**2)/(2.*NX)
      IF(I.EQ.NX) ESUM=ESUM-VO/(2.*8X)
 3006 CONTINUE
      RSUM=RSUM-(RHO(I,J)+RHO(I,J+1))/(2.*1.6E-19*NX)
 3002 CONTINUE
      EAVGS(K)=ESUM
      CHFIDS(K)=RSUM
      K=K+1
 3001 CONTINUE
      NYY=NY1
      DO 3003 L=1,NY1
      EAVG(L)=EAVGS(NYY)
      CHFID(L)=CHFIDS(NYY)
      NYY=NYY-1
 3003 CONTINUE
      KK=1
      M1=NY1+1
      M2=2*NY1
      DO 3004 M=M1,M2
      EAVG(M)=EAVGS(KK)
      CHFID(M)=CHFIDS(KK)
      KK=KK+1
 3004 CONTINUE
 3000 CONTINUE
      LL=1
      DO 3007 NN=1,NY1
      ECOLLS(LL)=-(EX(NX,NN)+EX(NX,NN+1))/2.
      LL=LL+1
 3007 CONTINUE
      L1=NY1
      DO 3008 L=1,NY1
      ECOLL(L)=ECOLLS(L1)
      L1=L1-1
 3008 CONTINUE
      L2=1
      I1=NY1+1
      I2=2*NY1
      DO 3009 I=I1,I2
      ECOLL(I)=ECOLLS(L2)
      L2=L2+1
 3009 CONTINUE
      VO=-1.*VO
      START=SSTART
      RETURN
      END
PROG > OK
```

APPENDIX B

LISTING OF CMAN

```
      SUBROUTINE CMAN (VW,NX,NY,SX,SV,PI,AC,NWIRE)
C   COOPERMAN SERIES DETERMINATION FOR VOLTAGE WIRE TO PLATE
C   FOR SUBROUTINE EFIELD
      REAL NUM,M,NWIRE
      LOGICAL LTEST
      COMMON /BLK13/VCOOP(15,15),NVII
      COMMON/BLK21/ECX(15,15),ECY(15,15),X1(15),Y1(15),AX(15),AY(15)
      COMMON /BLK22/ LTEST,RHO(15,15),V(15,15),EX(15,15),EY(15,15)
      NX1=NX-1
      NY1=NY-1
      DO 402 I=1,NX
      IF(NVII-1)301,300,301
  300 I=NX
  301 CONTINUE
      DO 430 J=1,NY
      X=FLOAT(I-1)*SX/FLOAT(NX1)
      IF(LTEST)X=X1(I)
      Y=FLOAT(J-1)*SY/FLOAT(NY1)
      IF(LTEST)Y=Y1(J)
      IF(X.EQ.0..AND.Y.EQ.0.)GO TO 440
      GO TO 450
 440  VCOOP(I,J)=VW
      GO TO 430
 450  CONTINUE
      M=-NWIRE
      NUM=0.0
      DENOM=0.0
      EX0=0.
      EY0=0.
      EXSUM=0,
      EYSUM=0.
  490 E1=PI*(Y-(2.*M*SY))/(2.*SX)
      F1=PI*X/(2.*SX)
      G1=PI*M*SY/SX
      H1=PI*AC/(2.*SX)
      E2=(EXP(E1)+EXP(-E1))/2.
      F2=COS(F1)
      G2=(EXP(G1)+EXP(-G1))/2.
      H2=COS(H1)
      TT=(E2-F2)/(E2+F2)
      TB=(G2-H2)/(G2+H2)
      F=ALOG(TT)
      G=ALOG(TB)
      NUM=NUM+F
      DENOM=DENOM+G
      H3=SIN(H1)
      F3=SIN(F1)
      E3=(EXP(F1)-EXP(-E1))/2.
      G3=(EXP(G1)-EXP(-G1))/2.
      SUMX=F3/(E2-F2)+F3/(E2+F2)
      SUMY=E3/(E2-F2)-E3/(E2+F2)
      S1=H3/(G2-H2)+H3/(G2+H2)
      S2=G3/(G2-H2)-G3/(G2+H2)
      EXSUM=EXSUM+SUMX
      EYSUM=EYSUM+SUMY
      EX0=EX0+S1
      EY0=EY0+S2
      IF(M.LT.NWIRE) GO TO 408
      GO TO 410
 408  M=M+1.0
```

```
      GO TO 490
410   VCOOP(I,J)=VW*NUM/DENOM
      ECX(I,J)=-(PI*VW/2,/SX/DENOM)*FXSUM
      ECY(I,J)=-(PI*VW/2./SX/DENOM)*FYSUM
430   CONTINUE
402   CONTINUE
 404  CONTINUE
      ECX(1,1)=-(PI*VW/2,/SX/DENOM)*FX0
      ECY(1,1)=-(PI*VW/2./SX/DENOM)*FY0
      RETURN
      END
```

APPENDIX C

LISTING OF EFLD4

```
      SUBROUTINE EFLD4 (UEQ,AC,VO,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINAL,VSTART,VW,ACDNTY,NWIRE,NEC,EBD,JI1,JI2)
C  EVALUATION OF FIELDS, SPACE CHARGE DENSITY, POTENTIAL , AND
C  CURRENT DENSITY FOR A WIRE-PLATE PRECIPITATOR
      REAL NWIRE,MAXS,MOBILT(15,15)
      LOGICAL LTEST
      DIMENSION RHO(15,15),EX(15,15),OLDRO(15,15),OLDV(15,15),
     1CDNSTY(15,15),V(15,15),EY(15,15),EAVGS(30),CHFIDS(30),ECOLLS(30)
      COMMON/BLK8/EAVG(30),CHFID(30)
      COMMON/BLK9/ECOLL(30)
      COMMON /BLK13/VCOOP(15,15),NVII
      COMMON/BLK17/NREAD,NPRNT
      COMMON/BLK21/ECX(15,15),ECY(15,15),X1(15),Y1(15),AX(15),AY(15)
      COMMON /BLK22/ LTEST,RHO,V,EX,EY
      DATA OLDRO/225*0./,OLDV/225*0./,CDNSTY/225*0./,MOBILT/225*0./
      NPRNT=6
      NPRNT=3
      NVII=2
      NVII=1
      IVCK=0
      VO=-1.*VO
      VW=-1.*VSTART
      RO=AC
      RELD=(293./TDK)*(P/1.)
      ROC=100.*RO
      RC=(ROC*RF*(30.*RELD+9.*SQRT(RELD/ROC)))/30.
      RC=RC/100.
      RC=AC
      EORO=ROC*RF*(30.*RELD+9.*SQRT(RELD/ROC))*1.E+03
      EO=EORO/AC
      DO 550 I=1,NX
      DO 550 J=1,NY
      MOBILT(I,J)=UEQ
  550 CONTINUE
      SSTART=START
      NITER=25
      NVITER=4000
      COEF=0.04
      VCK=0.05
      TESCF=0.005
      X1(1)=0.
      Y1(1)=0.
      PI=3.1416
      EPSO=8.854E-12
      ACDNTY=START
      MAXS=0.
      NX1=NX-1
      NY1=NY-1
      NX2=NX-2
      NY2=NY-2
      NX3=NX-3
      AX1=(SX-2.*RC)/FLOAT(NX3)
      AY1=(SY-RC)/FLOAT(NY2)
      BX=2.*(SX-2.*RC)/RC/FLOAT(NX3)/FLOAT(NX2)
      BY=2.*(SY-RC)/RC/FLOAT(NY2)/FLOAT(NY1)
      DO 2000 I=1,NX
      RI=I-1
      AX(I)=RI*BX*RC
      AX(1)=RC
      AX(1)=AC
      AX(NX1)=RC
      AX(NX)=AX(NX1)
      IF(I.EQ.1)GO TO 2000
      X1(I)=X1(I-1)+AX(I-1)
 2000 CONTINUE
      DO 2001 J=1,NY
      RJ=J-1
      AY(J)=RJ*BY*RC
      AY(1)=RC
      AY(1)=AC
      AY(NX)=AY(NX1)
      IF(J.EQ.1)GO TO 2001
      Y1(J)=Y1(J-1)+AY(J-1)
 2001 CONTINUE
      VA=ABS(VO)
      V1=ABS(VW)
      IFINA1=1
      LTEST=.TRUE.
      CALL EFLD3(UEQ,AC,VA,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINA1,VSTART,V1,ACDNTY,NWIRE,NEC,EBD,JI1,JI2)
      WRITE(NPRNT,3555)
 3555 FORMAT(1H1,10X,'ELECTROSTATIC SOLUTION AT CURRENT ONSET'//)
      CALL ENTER2(NX,NY)
      WRITE(NPRNT,8888) V(1,1),ACDNTY,AEPLT
      DO 1001 II=1,IFINAL
      IF(II.EQ.JI1) START=DSTART
      IF(II.GE.JI2) START=CSTART
      MAXS=MAXS+START
      ACDNTY=MAXS
 1526 CONTINUE
      QZERO=-2.*MAXS*SY*1.0E-03/(PI*UEQ*ROC*RF*(30.*RELD+9.*SQRT(RELD
     1/ROC)))
      VA=ABS(VO)
      V1=ABS(VW)
      IFINA1=1
      CALL EFLD3(UEQ,AC,VA,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINA1,VSTART,V1,ACDNTY,NWIRE,NEC,EBD,JI1,JI2)
      V(1,2)=V(1,1)
      V(2,1)=V(1,1)
      VW=V(1,1)
      WRITE(NPRNT,3560) ACDNTY
 3560 FORMAT(1H1,10X,'APPROXIMATE SOLUTION FOR CURRENT DENSITY OF ',
     1 1PE12.3,2X,'AMPS PER SQUARE METER'//)
      CALL OUTPUT(NX,NY)
      WRITE(NPRNT,8888) V(1,1),ACDNTY,AEPLT
      GO TO 1001
      Z=0
    2 CONTINUE
      F1=0.
      F2=0.
      V1=0.
      V2=0.
      V3=0.
    1 Z=Z+1
      IZ=Z
      IF(IZ.EQ.NITER) WRITE(NPRNT,1865)  NITER
 1865 FORMAT(1X,' CONVERGENCE ON CURRENT DENSITY CAN NOT BE OBTAINED IN'
     1 ,  I6,'  ITERATIONS')
      IF(IZ.EQ.NITER) GO TO 700
      LL=0
  300 LL=LL+1
      DO 315 I=1,NX1
      DO 315 J=1,NY
      OLDV(I,J)=V(I,J)
      OLDRO(I,J)=RHO(I,J)
  315 CONTINUE
      RHO(1,2)=QZERO
      RHO(2,1)=QZERO
      EX(2,1)=EO
      EY(1,2)=EO
      DO 301 I=1,NX
      DO 301 J=1,NY
      IF(I.EQ.1) GO TO 800
      IF(I.EQ.NX) GO TO 806
      AXS=AX(I-1)*AX(I)
      AXSUM=AX(I-1)+AX(I)
      AXS1=AX(I-1)*AX(I-1)
      AXS2=AX(I)*AX(I)
      GO TO 801
  806 CONTINUE
      AXS=AX(I-1)*AX(I-1)
      AXSUM=AX(I-1)+AX(I-1)
      AXS1=AXS
      AXS2=AXS
      GO TO 801
  800 CONTINUE
      AXS=AX(I)*AX(I)
      AXSUM=AX(I)+AX(I)
      AXS1=AX(1)*AX(1)
      AXS2=AX(1)*AX(1)
  801 CONTINUE
      IF(J.EQ.1) GO TO 802
      IF(J.EQ.NY) GO TO 803
      AYS=AY(J-1)*AY(J)
      AYSUM=AY(J-1)+AY(J)
      AYS1=AY(J-1)*AY(J-1)
      AYS2=AY(J)*AY(J)
      GO TO 804
  802 CONTINUE
      AYS=AY(J)*AY(J)
      AYSUM=AY(J)+AY(J)
      AYS1=AY(1)*AY(1)
      AYS2=AY(1)*AY(1)
      GO TO 804
  803 CONTINUE
      AYS=AY(J-1)*AY(J-1)
      AYSUM=AY(J-1)+AY(J-1)
      AYS1=AY(NY-1)*AY(NY-1)
      AYS2=AY(NY-1)*AY(NY-1)
  804 CONTINUE
      ASP=(AXS*AYS)/EPSO
      ASS=1./(2.*(AXS+AYS))
      IF((I.EQ.1.AND.J.LE.2).OR.(J.EQ.1.AND.I.LE.2)) GO TO 301
      IF(I.EQ.1.AND.J.NE.1) GO TO 304
      IF(I.EQ.NX) GO TO 340
      IF(I.NE.1.AND.J.EQ.1) GO TO 305
      IF(J.EQ.NY) GO TO 600
      GO TO 306
  600 V(I,NY)=ASS*((2.*AYS*(AX(I-1)*V(I+1,NY)+AX(I)*V(I-1,NY)))/AXSUM+
     12.*AXS*V(I,NY-1)+ASP*RHO(I,NY))
      EX(I,NY)=-(V(I+1,NY)*AX(I-1)*AX(I-1)-V(I-1,NY)*AX(I)*AX(I)-V(I,NY)
     1*(AX(I-1)*AX(I-1)-AX(I)*AX(I)))/(AX(I-1)+AX(I))/AX(I-1)/AX(I)
      EY(I,NY)=0.
      ALPHA=EPSO*(2.*AY(J-1)*EX(I,J)*MOBILT(I,J)+2.*AX(I-1)*EY(I,J)*
     1MOBILT(I,J)-AY(J-1)*EX(I,J)*MOBILT(I-1,J)-AX(I-1)*EY(I,J)*
     2MOBILT(I,J-1))/2./AX(I-1)/AY(J-1)/MOBILT(I,J)
      BETA=-EPSO*(AY(J-1)*EX(I,J)*RHO(I-1,J)+AX(I-1)*EY(I,J)*RHO(I,J-1))
     1  /AX(I-1)/AY(J-1)
      GO TO 302
  304 IF(I.EQ.1.AND.J.EQ.NY)  GO TO 350
      V(1,J)=ASS*(2.*AYS*V(2,J)+(2.*AXS*(AY(J)*V(1,J-1)+AY(J-1)*V(1,J+1)
     1))/AYSUM+ASP*RHO(1,J))
      EX(1,J)=0,
      EY(1,J)=-(V(1,J+1)*AY(J-1)*AY(J-1)-V(1,J-1)*AY(J)*AY(J)-V(1,J)
     1*(AY(J-1)*AY(J-1)-AY(J)*AY(J)))/(AY(J-1)+AY(J))/AY(J-1)/AY(J)
      ALPHA=EPSO*(2.*AY(J-1)*EX(I,J)*MOBILT(I,J)+2.*AX(1)*EY(I,J)*
     1MOBILT(I,J)-AY(J-1)*EX(I,J)*MOBILT(1,J)-AX(1)*EY(I,J)*
     2MOBILT(I,J-1))/2./AX(1)/AY(J-1)/MOBILT(I,J)
      BETA=-EPSO*(AY(J-1)*EX(I,J)*RHO(1,J)+AX(1)*EY(I,J)*RHO(I,J-1))
     1  /AX(1)/AY(J-1)
      GO TO 302
  350 V(1,NY)=ASS*(2.*AYS*V(2,NY)+2.*AXS*V(1,NY-1)+ASP*RHO(1,NY))
      EX(1,NY)=0,
      EY(1,NY)=0.
      GO TO 301
  305 V(I,1)=ASS*((2.*AYS*(AX(I-1)*V(I+1,1)+AX(I)*V(I-1,1)))/AXSUM+2.*
     1AXS*V(I,2)+ASP*RHO(I,1))
      EX(I,1)=-(V(I+1,1)*AX(I-1)*AX(I-1)-V(I-1,1)*AX(I)*AX(I)-V(I,1)*
     1(AX(I-1)*AX(I-1)-AX(I)*AX(I)))/(AX(I-1)+AX(I))/AX(I-1)/AX(I)
      EY(I,1)=0.
      ALPHA=EPSO*(2.*AY(1)*EX(I,J)*MOBILT(I,J)+2.*AX(I-1)*EY(I,J)*
     1MOBILT(I,J)-AY(1)*EX(I,J)*MOBILT(I-1,J)-AX(I-1)*EY(I,J)*
     2MOBILT(I,1))/2,/AX(I-1)/AY(1)/MOBILT(I,J)
      BETA=-EPSO*(AY(1)*EX(I,J)*RHO(I-1,J)+AX(I-1)*EY(I,J)*RHO(I,1))
     1  /AX(I-1)/AY(1)
      GO TO 302
  306 V(I,J)=ASS*((2.*AYS*(AX(I-1)*V(I+1,J)+AX(I)*V(I-1,J)))/AXSUM+(2.*
     1AXS*(AY(J)*V(I,J-1)+AY(J-1)*V(I,J+1)))/AYSUM+ASP*RHO(I,J))
      EX(I,J)=-(V(I+1,J)*AX(I-1)*AX(I-1)-V(I-1,J)*AX(I)*AX(I)-V(I,J)*
     1(AX(I-1)*AX(I-1)-AX(I)*AX(I)))/(AX(I-1)+AX(I))/AX(I-1)/AX(I)
      EY(I,J)=-(V(I,J+1)*AY(J-1)*AY(J-1)-V(I,J-1)*AY(J)*AY(J)-V(I,J)*
     1(AY(J-1)*AY(J-1)-AY(J)*AY(J)))/(AY(J-1)+AY(J))/AY(J-1)/AY(J)
      ALPHA=EPSO*(2.*AY(J-1)*EX(I,J)*MOBILT(I,J)+2.*AX(I-1)*EY(I,J)*
     1MOBILT(I,J)-AY(J-1)*EX(I,J)*MOBILT(I-1,J)-AX(I-1)*EY(I,J)*
     2MOBILT(I,J-1))/2./AX(I-1)/AY(J-1)/MOBILT(I,J)
      BETA=-EPSO*(AY(J-1)*EX(I,J)*RHO(I-1,J)+AX(I-1)*EY(I,J)*RHO(I,J-1))
     1  /AX(I-1)/AY(J-1)
      GO TO 302
  340 CONTINUE
      V(NX,J)=0.
      EY(NX,J)=0,
      EX(NX,J)=V(NX1,J)/AX(NX1)
      ALPHA=EPSO*(2.*AY(J-1)*EX(I,J)-AY(J-1)*EX(I,J)*MOBILT(I-1,J)/
     1  MOBILT(I,J))/2./AX(I-1)/AY(J-1)
      BETA=-EPSO*EX(NX,J)*RHO(NX1,J)/AX(NX1)
  302 CONTINUE
      RHO(I,J)=-ALPHA-SQRT(ABS(ALPHA*ALPHA-BETA))
  301 CONTINUE
      IF(LL.EQ.NVITER) WRITE(NPRNT,1866)  NVITER
 1866 FORMAT(1X,' CONVERGENCE ON POTENTIAL GRID CAN NOT BE OBTAINED IN
     1,I6,'  ITERATIONS ')
      IF(LL.EQ.NVITER) GO TO 700
      DO 320 I=1,NX1
      DO 320 J=1,NY
      IF(ABS(V(I.J)-OLDV(I,J)).LT. VCK) GO TO 320
      GO TO 300
  320 CONTINUE
      CONSTY(NX,1)=EX(NX,1)*MOBILT(NX,1)*RHO(NX,1)
      ACDNTY=CONSTY(NX,1)*AY(1)
  950 DO 900 J=2,NY
      CONSTY(NX,J)=EX(NX,J)*MOBILT(NX,J)*RHO(NX,J)
  900 CONTINUE
      DO 901 J=2,NY1
      ACDNTY=ACDNTY+(CONSTY(NX.J)+CONSTY(NX,J+1))*AY(J)/2.
  901 CONTINUE
      ACDNTY=ACDNTY/SY
C         ****************************************************
      IF(ACDNTY.LT.1.0E-08) GO TO 980
C         ****************************************************
 1000 CONTINUE
      F=ACDNTY-MAXS
      TEST=ABS(ACDNTY-MAXS)
      TEST1=TESCF*MAXS
      IF(TEST.LT.TEST1) GO TO 980
      V3=V(2,1)-COEF*V(2,1)*F/ABS(F)
      IF(F.EQ.0.)GO TO 980
      IF(F.LT.0.)F1=F
      IF(F.LT.0.)V1=V(2,1)
      IF(F.GT.0.)F2=F
      IF(F.GT.0.)V2=V(2,1)
      IF(F1*F2.LT.0.)V3=(V1+V2)/2.
      IF(F1*F2.LT.0.)V3=(V1*F2-V2*F1)/(F2-F1)
      WRITE(NPRNT,3710) F,V(2,1).ACDNTY,LL.IZ
 3710 FORMAT(10X,'F=',E11.3,5X,'V(2,1)',E11.3,5X,'ACDNTY=',
     1 E11.3,5X,'LL=',I5.5X,'IZ=',I5)
      V(2,1)=V3
      V(1,2)=V(2.1)
      ARG=ABS(2.*(V2-V1)/(V2+V1))
      FUN=ABS(1.-ACDLST/ACDNTY)
      IF(ARG.LT.1.0E-04.AND.FUN.LT.5.0E-02)GO TO 2
      ACDLST=ACDNTY
      GO TO 1
  980 CONTINUE
      V(1,2)=V(2.1)
      VW=V(2,1)+EO*(RC-AC)
      V(1,1)=VW
      EPLT=0.
      DO 1200 J=2,NY
      EPLT=EPLT+(EX(NX,J)+EX(NX,J-1))*AY(J-1)/2.
 1200 CONTINUE
      AEPLT=EPLT/SY
  700 CONTINUE
      WRITE (NPRNT,3565) ACDNTY
```

```
3565 FORMAT(1H1,10X,'NUMERICALLY INTEGRATED SOLUTION FOR CURRENT DENSIT
    1Y OF',1PE12.3,2X,'AMPS PER SQUARE METER'//)
     CALL OUTPUT(NX,NY)
     WRITE(NPRNT,8888) VW,ACDNTY,AEPLT
8888 FORMAT(38X,'VW = ',1PE11.4,2X,'ACDNTY = ',1PE11.4,2X,'AEPLT = ',1P
    1E11.4//)
     WRITE(NPRNT,3720) LL,IZ
3720 FORMAT(10X,'LL=',I5,5X,'IZ=',I5)
     IF(ABS(EX(NX,1)).LT.EBD) GO TO 1480
     WRITE(NPRNT,1481) VW,ACDNTY
1481 FORMAT(' THE BREAKDOWN FIELD NEAR THE PLATE IS EXCEEDED AT VW =',E
    111.4,1X,'AND ACDNTY =',E11.4)
     GO TO 1525
1480 CONTINUE
     IF(IVCK.EQ.1) GO TO 1525
     IF(ABS(VW).EQ.ABS(VO)) GO TO 1525
     IF(ABS(VW).GT.ABS(VO)) GO TO 1523
     OLDVW=VW
     OLDCD=ACDNTY
     GO TO 1524
1523 CONTINUE
     MAXS=ACDNTY-((ACDNTY-OLDCD)/(VW-OLDVW))*(VW-VO)
     VW=OLDVW
     IVCK=1
     GO TO 1526
1524 CONTINUE
1001 CONTINUE
1525 CONTINUE
     IF(NEC.NE.0) GO TO 3000
     K=1
     DO 3001 J=1,NY1
     RSUM=0.
     ESUM=0.
     DO 3002 I=1,NX
     IF(J.EQ.1) GO TO 3005
     ESUM=ESUM+(SQRT(EX(I,J)**2+EY(I,J)**2)+SQRT(EX(I,J+1)**2+
    1EY(I,J+1)**2))/(2.*NX)
     GO TO 3006
3005 CONTINUE
     ESUM=ESUM+SQRT(EX(I,J+1)**2+EY(I,J+1)**2)/(2.*NX)
     IF(I.EQ.NX) ESUM=ESUM-VO/(2.*SX)
3006 CONTINUE
     RSUM=RSUM-(RHO(I,J)+RHO(I,J+1))/(2.*1.6E-19*NX)
3002 CONTINUE
     EAVGS(K)=ESUM
     CHFIDS(K)=RSUM
     K=K+1
3001 CONTINUE
     NYY=NY1
     DO 3003 L=1,NY1
     EAVG(L)=EAVGS(NYY)
     CHFID(L)=CHFIDS(NYY)
     NYY=NYY-1
3003 CONTINUE
     KK=1
     M1=NY1+1
     M2=2*NY1
     DO 3004 M=M1,M2
     EAVG(M)=EAVGS(KK)
     CHFID(M)=CHFIDS(KK)
```

```
      KK=KK+1
 3004 CONTINUE
 3000 CONTINUE
      LL=1
      DO 3007 NN=1,NY1
      ECOLLS(LL)=-(EX(NX,NN)+EX(NX,NN+1))/2.
      LL=LL+1
 3007 CONTINUE
      L1=NY1
      DO 3008 L=1,NY1
      ECOLL(L)=ECOLLS(L1)
      L1=L1-1
 3008 CONTINUE
      L2=1
      I1=NY1+1
      I2=2*NY1
      DO 3009 I=I1,I2
      ECOLL(I)=ECOLLS(L2)
      L2=L2+1
 3009 CONTINUE
      VO=-1.*VO
      START=SSTART
      RETURN
      END
```

APPENDIX D

LISTING OF OUTPUT

```
      SUBROUTINE  OUTPUT(NX,NY)
      DIMENSION RHO(15,15),EX(15,15),OLDRO(15,15),OLDV(15,15),
     1CONSTY(15,15),V(15,15),EY(15,15),EAVG8(30),CHFID8(30),ECOLL8(30)
      COMMON/BLK8/EAVG(30),CHFID(30)
      COMMON/BLK9/ECOLL(30)
      COMMON /BLK13/VCOOP(15,15),NVII
      COMMON/BLK21/ECX(15,15),ECY(15,15),X1(15),Y1(15),AX(15),AY(15)
      COMMON /BLK22/ LTEST,RHO,V,EX,EY
      COMMON/BLK17/NREAD,NPRNT
      COMMON /BLK20/ R ,LVAR,LCHAN ,EORO,EPSO,PI,LINTEG,FAC,NHALF,NVITER
     1,  NITER,VCK,IPOT,COEF,TESCF,RELD,FAC2,VCOR,ECOR
      NPRNT=6
      NPRNT=3
      N2=(NY-1)/9
      N1=NY-8*N2
      WRITE(NPRNT,10) (J,J=1,9)
   10 FORMAT(14X,      9('Y(',I2,')',8X))
      WRITE(NPRNT,11)  (Y1(J),J=1,9)
   11 FORMAT(9X,9(1PE13,3)//)
      DO 292 I=1,NX
      WRITE(NPRNT,30)
     1            I,(RHO(I,J),J=1,9),(V(I,J),J=1,9),X1(I),(EX(I,J),J=1,9)
     1 ,(EY(I,J),J=1,9)
   30 FORMAT(4X,'X(',I2,')',9E13.5/9X,9F13.3/3X,F6.4,   9E13.5/9X,
     1  9E13.5/)
  292 CONTINUE
      WRITE(NPRNT,850) (CONSTY(NX,J),J=1,9)
  850 FORMAT(3X,9E13.5)
      WRITE(NPRNT,15)  (J,J=N1,NY,N2)
   15 FORMAT(/14X, 9('Y(',I2,')',8X))
      WRITE(NPRNT,11)  (Y1(J),J=N1,NY,N2)
      DO 293 I=1,NX
      WRITE(NPRNT,30)I,(RHO(I,J),J=N1,NY,N2),(V(I,J),J=N1,NY,N2),X1(I),
     1  (EX(I,J),J=N1,NY,N2),(EY(I,J),J=N1,NY,N2)
  293 CONTINUE
      WRITE(NPRNT,850) (CONSTY(NX,J),J=N1,NY,N2)
      RETURN
      ENTRY ENTER2(NX,NY)
      N2=(NY-1)/9
      N1=NY-8*N2
      WRITE(NPRNT,15) (J,J=1,9)
      WRITE(NPRNT,11)  (Y1(J),J=1,9)
      DO 3510 I=1,NX
 3510 WRITE(NPRNT,3550)I,(VCOOP(I,J),J=1,9),(ECX(I,J),J=1,9),X1(I),
     1     (ECY(I,J),J=1,9)
      WRITE(NPRNT,15)  (J,J=N1,NY,N2)
      WRITE(NPRNT,11)  (Y1(J),J=N1,NY,N2)
      DO 3520 I=1,NX
 3520 WRITE(NPRNT,3550)I,(VCOOP(I,J),J=N1,NY,N2),(ECX(I,J),J=N1,NY,N2),


     1 X1(I),(ECY(I,J),J=N1,NY,N2)
 3550 FORMAT(4X,'X(',I2,')',9F13.0/9X,9E13.3/3X,F6.4,   9E13.3/)
      RETURN
      END
```

APPENDIX E

LISTING OF RATE

```
      FUNCTION RATE (ECHARG,SCHARG,NUMINC,CONST,EZERO,V,RSIZE,ECONST,
     *CMKS,RR,FCONST,FACTOR,COEFF,AFID,NTIME,NUMBER)
      REAL INTGRL,NE,NUMBER,NTIME
      DIMENSION T(3),A(3)
      DATA T/-0.77459667,0.0,0.77459667/
      DATA A/0.55555556,0.88888889,0.55555556/
      NE=-NUMBER*ECHARG
      PI=3.1415927
      IF(NUMBER-SCHARG)7005,7006,7006
 7005 CALL ARCCOS(NUMBER,SCHARG,THZERO)
      IF(THZERO.LE.1.E-05) GO TO 7006
      IF(1.57-THZERO) 7011,7011,7015
 7015 CONTINUE
      GO TO 7007
 7006 THZERO=0.
 7007 YFUC=0.0
      DO 7002 I=1,3
      THETA=T(I)*(PI-2.*THZERO)/4.+(PI+2.*THZERO)/4.
      CTHETA=COS(THETA)
      TCONST=CONST*CTHETA
      ECOS=EZERO*CTHETA
      C1=-NE/(CMKS*ECOS)
      CO=TCONST/(2.*ECOS)
      CALL ZERO(C1,CO,RZERO)
      ARG1=-(NUMBER*V*(RZERO-RSIZE)/RZERO+(ECONST-RR*RZERO+FCONST/RZERO*
     1*2)*CTHETA)
      IF(ABS(ARG1).GT.30.0) GO TO 7025
      YVAL=EXP(ARG1)*SIN(THETA)
      GO TO 7026
 7025 YVAL=0.
 7026 CONTINUE
      YFUC=YFUC+A(I)*YVAL
 7002 CONTINUE
      RATE1=(PI-2.*THZERO)/4.*YFUC*FACTOR*AFID
      GO TO 7012
 7011 RATE1=0.
 7012 CONTINUE
      ARG3=-V*NUMBER
      IF(ABS(ARG3).GT.30.0) GO TO 7031
      RATE2=FACTOR*EXP(ARG3)*AFID
      GO TO 7032
 7031 RATE2=0.
 7032 CONTINUE
      IF(NUMBER-SCHARG)7008,7009,7009
 7008 RATE3=COEFF*(1.-NUMBER/SCHARG)**2*AFID
      GO TO 7010
 7009 RATE3=0.
 7010 CONTINUE
      RATE=RATE1+RATE2+RATE3
      RETURN
      END
```

APPENDIX F

COMPLETE LISTING OF THE COMPUTER PROGRAM

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```
C                          ***********************************************************
C                          *                                                         *
C                          *               E.P.A.-SO.R.I. ESP MODEL                  *
C                          *  THIS PROGRAM IS DESIGNED TO COMPUTE PERFORMANCE        *
C                          *  OF A WIRE-PLATE PRECIPITATOR USING DESIGN AND          *
C                          *  OPERATING PARAMETERS. THE PROGRAM WAS DEVELOPED BY     *
C                          *  PERSONNEL OF THE SOUTHERN RESEARCH INSTITUTE FOR       *
C                          *  DR. LES SPARKS OF THE PARTICULATE TECHNOLOGY           *
C                          *  BRANCH, INDUSTRIAL ENVIRONMENTAL RESEARCH LAB,         *
C                          *  ENVIRONMENTAL PROTECTION AGENCY, PROJECT OFFICER.      *
C                          *                REVISION 2, AUG., 1979                   *
C                          *                                                         *
C                          ***********************************************************
C
C
      REAL  NWIRE,LTHICK,JPART,JION,LINC,NWS,LINCS
      INTEGER VISKIP,VISAME
      DIMENSION CHKSUM(20)
      COMMON/BLK1/DIAM(20),ONO(20),DXS(20),XMV(20),PCNT(20),RAD(20),
     1CCF(20),PRCU(21)
      COMMON/BLK2/LSECT(10),LINCS(10),PS(10)
      COMMON/BLK3/VG,ATOTAL,DD,ETAO,DL,PL,RHO
      COMMON/BLK4/NS
      COMMON/BLK5/ZMMDI,SIGMI,NOMID,NRAPD,TDK,NUMSEC,NEFF,NTEMP,SFIT
      COMMON/BLK6/VOL(20),XNO(20),Q(20),WS(20),ITL(40),DM(45),AS(10),
     1VOS(10),TCS(10),WLS(10),ACS(10),BS(10),SYS(10),VGS(10),VGASS(10),
     2TEMPS(10),VISS(10),QSAT(20),U,E,EPSO,PI,ERAVG,BC,TEMP,EPS,VAVC,
     3OLDQ(20),OLDXNO(20),RFS(10),START1(10),START2(10),START3(10),
     4VSTAR(10)
      COMMON/BLK7/XDC(45,20)
      COMMON/BLK8/EAVG(30),CHFID(30)
      COMMON/BLK9/ECOLL(30)
      COMMON/BLK10/ECLEAN(30)
      COMMON/BLK11/ENDPT(21),NENDPT
      COMMON/BLK12/ARD50(10),ARSIGM(10),ASNUCK(15),AZNUMS(15),AZIGGY(15)
      COMMON /BLK13/VCOOP(15,15),NVII
      COMMON/BLK14/TMFP,NVI,NV1
      COMMON/BLK15/NPRINT,NSECT,SLNGTH,A,VO,TC,B,AC,WL,CL,CD,ET,SY,
     1VGAS,P,VIS,W,LINC,XPI,RIOVR,EPLT,AFID,XCD,ZMD,
     2WT,LTHICK,JPART,JION,I,ROVRI
      COMMON/BLK16/NCALC,NT,VRATIO,NF
      COMMON/BLK17/NREAD,NPRNT
      COMMON/BLK18/SCOREF,CZMDL,CSIGMD,NRUN,SNUCK,ZIGGY,RMMD,RSIGMA
      COMMON/BLK19/LK,DV,NN,NUMINC,NX,NY,NDATA,NEST,NDIST,NITER,IFINAL,
     1JI1,JI2,VISKIP,VISAME,US,FPATH,EBD,NDSET,NWS(10),D50,SIGMAP
      COMMON/BLK20/SCHARG,CHRFID,TIMEI,TIMEF,V,FACTRE,RSIZE,CNUMBR,J,IT,
     1ITER,OLDQF(20),OLDQT(20),SOLDQF(20),SOLDQT(20)
      EXTERNAL RATE
      NREAD=2
      NPRNT=3
C
C   CONSTANTS
C
      NVII=0
      IFINAL=1
      JI1=0
      JI2=0
      PI = 3.1415927
      E = 1.6E-19
      BC=1.38E-23
      EPS0 = 8.85E-12
      CMKS=4.*PI*EPS0
 4000 CONTINUE
C
C
      NOSET=0
      READ(NREAD,5) NENDPT,NDATA
    5 FORMAT(2I2)
      IF(NENDPT-99) 8500,9999,9999
 8500 CONTINUE
      NS=NENDPT-1
      READ(NREAD,7) ITL
    7 FORMAT(40A2)
      GO TO(9400,9401,9402,9403),NDATA
 9400 CONTINUE
      READ(NREAD,4864) NFST,NDIST,NVT,NX,NY,NITER,NCALC,NRAPD,NEFF,
     1NTEMP,NONID
 4864 FORMAT(11I2)
      NVI=NVT
      IF(NVI.EQ.3)NVTI=1
      IF(NVI.EQ.3)NVT=1
      IF(NVI.EQ.4)NVTI=2
      IF(NVI.EQ.4)NVT=2
      IF(NCALC.EQ.0) READ(NREAD,5) NN,NUMINC
      IF(NVI.EQ.2) READ(NREAD,8530) TFINAL,JI1,JI2,VISKIP,VISAME
 8530 FORMAT(5I2)
      READ(NREAD,6) DL,PL,ETAO,DD,FPS,VRATIO,US,FPATH,ERD,RHO
    6 FORMAT(9F8.0,E8.2)
C
C         CONVERSION
C
      PL = PL * 0.305
      DL = DL * 2.29E-03
      RHO = RHO/100.0
      DV = DL / DD
C
      IF(NRAPD.GT.1) READ(NREAD,8531) (ARD50(I),ARSIGM(I),I=2,NRAPD)
 8531 FORMAT(10(2F4.0))
      READ(NREAD,8532) (ASNUCK(I),AZIGGY(I),AZNUMS(I),I=1,NONID)
 8532 FORMAT(6(3F4.0))
      READ(NREAD,4) (ENDPT(I),I=1,NENDPT)
    4 FORMAT(10F8.0)
      DO 4740 I=1,NS
      DIAM(I)=((ENDPT(I)+ENDPT(I+1))/2.)*1.E-06
      RAD(I)=DIAM(I)/2.
 4740 CONTINUE
 9401 CONTINUE
      IF(NDIST.EQ.2) READ(NREAD,8533) D50,SIGMAP
 8533 FORMAT(2F8.0)
      IF(NDIST.EQ.1) READ(NREAD,4) (PRCU(I),I=1,NENDPT)
      IF(NDIST.EQ.2) GO TO 8521
      DO 3 I=1,NS
      PCNT(I)=(PRCU(I+1)-PRCU(I))*1.E-02
    3 CONTINUE
      CALL LNFIT(PRCU,D50,SIGMAP,GFIT)
      ZMMDT=D50
      SIGMI=SIGMAP
      GO TO 8522
 8521 CONTINUE
      CALL LNDIST(D50,SIGMAP,PRCU,PCNT)
      ZMMDI=D50
      SIGMI=SIGMAP
 8522 CONTINUE
      IF(NDATA.GT.1) GO TO 8534
      READ(NREAD,770) NUMSEC,(LSECT(I),I=1,NUMSEC)
  770 FORMAT(I2,10I2)
      DO 1143 NSECT=1,NUMSEC
      READ(NREAD,762) AS(NSECT),VOS(NSECT),TCS(NSECT),NLS(NSECT),
     1ACS(NSECT),BS(NSECT),NWS(NSECT),SVS(NSECT),VGS(NSECT)
     2,VGASS(NSECT),TEMPS(NSECT),PS(NSECT),VISS(NSECT),LINCS(NSECT)
  762 FORMAT(7(E11.4))
      IF(NVI.EQ.1) GO TO 1143
      READ(NREAD,762) RFS(NSECT),START1(NSECT),START2(NSECT),START3
     1(NSECT),VSTAR(NSECT)
 1143 CONTINUE
      GO TO 8534
 9402 CONTINUE
      READ(NREAD,9410) (VGS(I),VGASS(I),I=1,NUMSEC)
 9410 FORMAT (3(2E11.4))
      GO TO 8534
 9403 CONTINUE
      READ(NREAD,9410) (VOS(I),TCS(I),I=1,NUMSEC)
 8534 CONTINUE
      LK=0
      WRITE(NPRNT,17)
   17 FORMAT('1')
      NI = 2*NY - 2
      NF=0
      DO 8649 KA=1,NUMSEC
      NF=NF+LSECT(KA)
 8649 CONTINUE
C
C
C
      DO 1 I = 1 ,NS
      VOL(I) = PCNT(I) * DV
    1 CONTINUE
      NPRINT=0
      IF(NVI.EQ.1) ITER=0
  305 CONTINUE
      IF(NVI.EQ.1) ITER=ITER+1
      DO 9 I = 1, NS
      DXS(I)=0.
      XNO(I) = VOL(I)/ ( 4./3. * PI * RAD(I)**3 )
      ONO(I) = XNO(I)
    9 CONTINUE
      CALL PRTINP
C
C
C*********************************************************************
C
C       START  INCREMENTAL ANALYSIS OF PRECIPITATOR
C
C*********************************************************************
C
      LK=1
      ZNT=0.
      RATIO=(EPS-1.)/(EPS+2.)
      G=EPS+2.
      INDEX=0
      NSECT=1
      NCOOP=0
      DO 3000 I=1,NF
      IF(NVI.EQ.2) ITER=0
      INDEX=INDEX+1
      IF(I.EQ.1) GO TO 761
      IF(INDEX-LSECT(NSECT)) 760,760,761
  761 CONTINUE
      NCOOP=1
      NPRINT=1
      IF(I.EQ.1) GO TO 760
      NSECT=NSECT+1
      INDEX=1
  760 CONTINUE
      IF(NCOOP.NE.1) GO TO 764
      A=AS(NSECT)*9.3E-02
      VO=VOS(NSECT)
      TC=TCS(NSECT)
      WL=WLS(NSECT)*0.305
      AC=ACS(NSECT)*2.54E-02
      SX=HS(NSECT)*2.54E-02
      SY=SYS(NSECT)*2.54E-02
      NWIRE=NWS(NSECT)
      VG=VGS(NSECT)*4.73E-04
      VGAS=VGASS(NSECT)*.305
      TEMP=TEMPS(NSECT)+459.
      P=PS(NSECT)
      VIS=VISS(NSECT)
      LINC=LINCS(NSECT)*0.305
      RF=RFS(NSECT)
      START=START1(NSECT)
      DSTART=START2(NSECT)
      CSTART=START3(NSECT)
      VSTART=VSTAR(NSECT)
      SLNGTH=FLOAT(LSECT(NSECT))*LINC
      B=SX
C
C CALCULATE ION MEAN FREE PATH
C
      TDK=TEMP/1.8
      ZMV=8.205E-05*TDK/P
      ZMFP=(8.205E-05*TDK)/(1.414*PI*1.6E-19*6.02E+23*P)
      IMFP=ZMFP*FPATH
      VAVG=SQRT((8.*8.314E+07*TDK)/(3.14*32.))
      VAVC=VAVG/100.
      VC=E**2/(BC*TDK)
      FACTRC=(PI*VAVC)/2.
C
C   COMPUTE ION MOBILITY CORRECTED FOR TEMPERATURE AND PRESSURE
C
      U=(TDK/273.16)*US*(1.0/P)
C
      COEFFC=PI*U*E
      TINC=LINC/VGAS
      IF(NVI.EQ.1) GO TO 4675
      DTINC = TINC/FLOAT(NI)
 4675 CONTINUE
C
C     COMPUTE WEIGHT OF DUST
C
```

```
      W = DL * VG
C
      DO 6993 J=1,NS
      CCF(J)=1+(ZMFP/RAD(J))*(1.257+.4*EXP(-1.1*RAD(J)/ZMFP))
 6993 CONTINUE
      IF(NVI.EQ.2) GO TO 4676
      ERAVG=VO/SX
      DO 6989 L=1,NS
      QSAT(L)=(4.*PI*EPSO*(RAD(L)+ZMFP)**2)*ERAVG*(1.+2.*((EPS-1.)/
     1(EPS+2.))*(RAD(L)/(RAD(L)+ZMFP))**3)*VRATIO
 6989 CONTINUE
      R=(E*ERAVG)/(BC*TDK*(EPS+2.))
      RR=(E*ERAVG)/(BC*TDK)
      RG=R*G
 4676 CONTINUE
      NCOOP=0
      IF(NVI.EQ.2) GO TO 4677
      IF(NFST.EQ.2) GO TO 4678
      VW=-1.*VO
      CALL CHAN(VW,NX,NY,SX,SY,PI,AC,NWIRE)
      GO TO 4678
 4677 CONTINUE
      UEQ=0
      NEC=0
      IF((VISAME.EQ.1).AND.(NSECT.GT.1)) GO TO 5564
      IF((VISAME.EQ.1).AND.(NDSET.GT.1)) GO TO 5564
      WRITE(NPRNT,7140) NSECT
 7140 FORMAT(//23X,'CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE
     1 RELATIONSHIP FOR SECTION NO. ',I2//)
      IF(NVII.EQ.2)CALL EFLD3(UEQ,AC,VO,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINAL,VSTART,VW,ACDNTY,NWIRE,NEC,ERD,JI1,JI2)
      IF(NVII.NE.2)CALL EFLD2(UEQ,AC,VO,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINAL,VSTART,VW,ACDNTY,NWIRE,NEC,ERD,JI1,JI2)
      DO 7919 NZ=1,NT
      ECLEAN(NZ)=ECOLL(NZ)
 7919 CONTINUE
      CDCLN=ACDNTY
 5564 CONTINUE
      VOS(NSECT)=-VW
 4678 CONTINUE
      IF(NVI.EQ.2) TC=CDCLN*A
C
C   COMPUTE CURRENT DENSITY
      CD = TC / A
C
C
C   COMPUTE ELECTRIC FIELD IN DEPOSIT
      ET = CD * RHO
C
C
C   COMPUTE CURRENT PER  M. OF CORONA WIRE
C
      CL = TC / WL
C
 768  CONTINUE
      IF(NVI.EQ.1) GO TO 4679
      ITER=ITER+1
      USUM=0.
      WSSUM=0.
      RHOSUM=0.
      GO TO 4680
 4679 CONTINUE
      CALL SPCHG1(SW,ROVRI,OROVRI,XS,ETAPF,DN,QSAT,XNO,W,LSECT,TC,VG,
     1FTAD,FID,AFID,AVGFID,XCD,U,UEQ,I,NSECT,LINC,PL,CD,E,ERAVG,NS,XPI)
      CHRFID=AFID
 4680 CONTINUE
C
C***********************************************************************
C
C          START PARTICLE SIZE LOOP
C
C***********************************************************************
C
      PROT=0.0
      WT = 0.
      JPART=0.
C
C   COMPUTE CHARGE ON EACH PARTICLE AFTER ONE INCREMENT OF TRAVEL
C
      IF(NVI.EQ.1) GO TO 4681
      II = 0
      SERAVG = 0.0
 6337 CONTINUE
      II = II + 1
      CHRFID=CHFID(II)
      ERAVG=EAVG(II)
      SERAVG = SERAVG + ERAVG/NI
      DO 9130 L=1,NS
      QSAT(L)=(4.*PI*EPS0*(RAD(L)+THFP)**2)*ERAVG*(1.+2.*((EPS-1.)/
     1(EPS+2.))*(RAD(L)/(RAD(L)+THFP))**3)*VRATIO
 9130 CONTINUE
      R=(E*ERAVG)/(BC*TDK*(EPS+2.))
      RR=(E*ERAVG)/(BC*TDK)
      FG=R*G
 4681 CONTINUE
      DO 2900 J = 1, NS
      IF(NVI.EQ.1) GO TO 4682
      OLDQ(J)=Q(J)
      IF(II.NE.1) GO TO 426
 4682 CONTINUE
      IF(I.NE.1) GO TO 426
      IF(J.GT.1) GO TO 428
      TIMEI=0.
      XIPC=0.
      IF(NVI.EQ.2) GO TO 4683
      TIMEF=TINC
      IF(NCALC.EQ.0) H=TINC/NN
      GO TO 4684
 4683 CONTINUE
      TIMEF=DTINC
      IF(NCALC.EQ.0) H=DTINC/NN
 4684 CONTINUE
      GO TO 428
  426 CONTINUE
      IF(NVI.EQ.1) GO TO 4685
      IF(J.GT.1) GO TO 429
      TIMEI=TIMEF
      IF((ITER.GT.1).AND.(II.EQ.1)) TIMEI=TIMEI-TINC
      TIMEF=TIMEF+DTINC
      IF(NCALC.EQ.0) H=DTINC/NN
  429 CONTINUE
      IF(IT.NE.1) GO TO 8242
      XIPC=XDC(I-1,J)/1.6E-19
      GO TO 8243
 8242 CONTINUE
      XIPC=XDC(I,J)/1.6E-19
 8243 CONTINUE
      GO TO 4686
 4685 CONTINUE
      IF(J.GT.1) GO TO 4687
      TIMEI=FLOAT(I-1)*TINC
      TIMEF=FLOAT(I)*TINC
      IF(NCALC.EQ.0) H=TINC/NN
 4687 XIPC=XDC(I-1,J)/1.6E-19
 4686 CONTINUE
  428 CONTINUE
      RSIZE=RAD(J)
      SCHARG=QSAT(J)/1.6E-19
      DCONST=RATIO*RSIZE**3
      CONST=2.*DCONST*ERAVG
      S=3.*RSIZE
      V=VC/(RSIZE*CMKS)
      ECONST=S*R
      ECONST=RG*DCONST
      FACTRE=FACTRC*RSIZE**2
      COEFF=(COEFFC*SCHARG)/CMKS
      IF(I.LE.2) GO TO 5850
      IF(NVI.EQ.1) GO TO 5851
      IF((II.EQ.1).AND.(ITER.EQ.1)) GO TO 5851
      GO TO 5852
 5851 CONTINUE
      IF(I.EQ.3) GO TO 5853
      IF(NSECT.EQ.1) GO TO 5680
      IF((INDEX.EQ.1).AND.(VOS(NSECT).GT.VOS(NSECT-1))) GO TO 5850
 5680 CONTINUE
      IF(CHKSUM(J).LE.0.005) GO TO 5854
 5853 CONTINUE
      CHKSUM(J)=(XDC(I-1,J)-XDC(I-2,J))/XDC(I-1,J)
 5852 CONTINUE
      IF(NSECT.EQ.1) GO TO 5681
      IF((INDEX.EQ.1).AND.(VOS(NSECT).GT.VOS(NSECT-1))) GO TO 5850
 5681 CONTINUE
      IF(CHKSUM(J).GT.0.005) GO TO 5850
 5854 CONTINUE
      Q(J)=XDC(I-1,J)
      GO TO 5855
 5850 CONTINUE
      IF((NCALC.EQ.1).OR.(NFST.EQ.2)) GO TO 8180
      CALL CHARGM(E,SCHARG,NUMINC,CONST,ERAVG,V,RSIZE,ECONST,CMKS,RR,
     1FCONST,FACTRE,COEFF,CHRFID,RATE,H,TIMEI,XIPC,NN,CTIME,CNUMBR)
      GO TO 8181
 8180 CONTINUE
      CALL CHGSUM
 8181 CONTINUE
      Q(J)=CNUMBR*1.6E-19
      IF((TIMEI.EQ.0.).AND.(CNUMBR.GT.SCHARG)) Q(J)=SCHARG*1.6E-19
 5855 CONTINUE
      XDC(I,J)=Q(J)
      IF(NVI.EQ.1) GO TO 2900
C
```

```
C   COMPUTE MIGRATION VELOCITY FOR EACH SIZE RANGE
C
      EMV=(Q(J)*ECOLL(II))/(6.*PI*RAD(J)*VIS)
      IF(ITER.EQ.1) EMV=(Q(J)*ECLEAN(II))/(6.*PI*RAD(J)*VIS)
      EMV=CCF(J)*EMV
      XMV(J)=EMV
C
C   COMPUTE EFFICIENCY FOR EACH SIZE RANGE
C
      X=(-A*EMV)/(VG*FLOAT(LSECT(NSECT))*FLOAT(NI))
C
      EFF =  1. - EXP( X )
C
C     COMPUTE NUMBER OF PARTICLES REMOVED IN EACH SIZE RANGE
C
      IF(ITER.EQ.1) GO TO 3761
      IF(II.NE.1) GO TO 3763
      XNO(J)=OLDXNO(J)
      GO TO 3763
 3761 CONTINUE
      IF(II.NE.1) GO TO 3763
      OLDXNO(J)=XNO(J)
 3763 CONTINUE
      DXNO=XNO(J)*EFF
      IF(ITER.NE.NITER) GO TO 3765
      DXS(J)=DXS(J)+DXNO
      WSSUM=DXNO*(1.33333*PI*RAD(J)**3)*DD
      WS(J)=WS(J)+WSSUM
      WT=WT+WSSUM
C
C   CALCULATE THE CURRENT DENSITY AT THE PLATE DUE TO THE PARTICULATE
      JPART=JPART+(FLOAT(LSECT(NSECT))*VG*DXNO*Q(J)*FLOAT(NI))/A
 3765 CONTINUE
      XNO(J)=XNO(J)-DXNO
C
 2900 CONTINUE
      IF(NVI.EQ.1) GO TO 9131
      CALL SPCHG2(NS,XNO,VIS,RAD,LINC,E,U,ERAVG,DNSION,
     1DELTNP,SUMMOB,PNUM,RHOP,TCHRG,PMOB,TDNSP,RDNSI,AFID,UEQ,AVGFID,
     2RIOVR,I,XS,ETAO,PL,ETAPF,CCF,XPI,OLDQ,Q,II,NSECT)
      USUM=USUM+UEQ
      RHOSUM=RHOSUM+RIOVR
 5676 CONTINUE
      IF(II.LT.NI) GO TO 6337
      UEQ=USUM/FLOAT(NI)
      RIOVR=RHOSUM/FLOAT(NI)
      IF(I.EQ.1) GO TO 376
      IF(RIOVR.GT.0.99) GO TO 375
  376 CONTINUE
      IF((VISKIP.EQ.1).OR.(NEST.EQ.2)) GO TO 3187
      WRITE(NPRNT,7141) I
 7141 FORMAT(//23X,'DIRTY GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE
     1 RELATIONSHIP FOR INCREMENT NO. ',I2//)
      NEC=1
      START=START1(NSECT)*(UEQ/U)
      IF(NVIT.EQ.2)CALL EFLD3(UEQ,AC,VO,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINAL,VSTART,VW,ACDNTY,NWIRE,NEC,ERD,JI1,JI2)
      IF(NVIT.NE.2)CALL EFLD2(UEQ,AC,VO,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINAL,VSTART,VW,ACDNTY,NWIRE,NEC,ERD,JI1,JI2)
      GO TO 3188
 3187 CONTINUE
      ACONTY=CDCLN*(UEQ/U)
 3188 CONTINUE
      EPLT=-1.*AEPLT
      XCD=ACONTY*100000.
  375 CONTINUE
      IF(ITER.NE.NITER) GO TO 1050
      IF(INDEX.EQ.1) SUMCD=0.
      IF(INDEX.EQ.1) SUMVO=0.
      SUMCD=SUMCD+ACONTY
      SUMVO=SUMVO-VW
      IF(INDEX.EQ.LSECT(NSECT)) TCS(NSECT)=(SUMCD*A)/FLOAT(LSECT(NSECT))
      IF(INDEX.EQ.LSECT(NSECT)) VOS(NSECT)=SUMVO/FLOAT(LSECT(NSECT))
 1050 CONTINUE
      IF(ITER.LT.NITER) GO TO 764
      JPART=JPART/FLOAT(NI)
      GO TO 4688
 9131 CONTINUE
      IF(UEQ.LT.1.0E-4)UEQ=1.0E-4
      IF(INDEX.EQ.1) GO TO 377
      IF(UEQ.NE.1.0E-4) GO TO 9133
      IF(UEQ.EQ.1.0E-4)EPLT=SKIP
      GO TO 9132
 9133 CONTINUE
      SIGMA=OROVRI-ROVRI
      SIGMA=ABS(SIGMA)
      IF(SIGMA.LT..01) GO TO 9132
  377 CONTINUE
      IF(NEST.EQ.2) GO TO 8182
      RF=1.0
      IF(NVIT.EQ.1)CALL EFLD3(UEQ,AC,VO,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,OSTART,CSTART,IFINAL,VSTART,VW,CD,NWIRE,NFC,EBD,JI1,JI2)
      IF(NVIT.NE.1)CALL EFLD1(UEQ,CD,AC,VO,SX,SY,NX,NY,TDK,P,AEPLT,
     1VERGE,CVERGE)
      EPLT=-1.*AEPLT
      GO TO 8183
 8182 CONTINUE
      EPLT=ERAVG/1.75
 8183 CONTINUE
      SKIP=EPLT
 9132 OROVRI=ROVRI
      DO 2965 J=1,NS
C
C   COMPUTE MIGRATION VELOCITY FOR EACH SIZE RANGE
C
      EMV=(Q(J)*EPLT)/(6.*PI*RAD(J)*VIS)
      EMV=CCF(J)*EMV
      XMV(J)=EMV
C
C   COMPUTE EFFICIENCY FOR EACH SIZE RANGE
C
      X=(-A*EMV)/(VG*FLOAT(LSECT(NSECT)))
C
      EFF =  1. - EXP( X )
C
C     COMPUTE NUMBER OF PARTICLES REMOVED IN EACH SIZE RANGE
C
      DXNO=XNO(J)*EFF
      DXS(J)=DXS(J)+DXNO
      WS(J)=DXNO*(1.33333*PI*RAD(J)**3)*DD
      XNO(J)=XNO(J)-DXNO
      WT=WT+WS(J)
C
C   CALCULATE THE CURRENT DENSITY AT THE PLATE DUE TO THE PARTICULATE
      JPART=JPART+(FLOAT(LSECT(NSECT))*VG*DXNO*Q(J))/A
C
 2965 CONTINUE
 4688 CONTINUE
      ZWT=ZWT+WT
C
C   CALCULATE THE CURRENT DENSITY AT THE PLATE DUE TO IONS
      JION=CD-JPART
C
C
C   CALCULATE THICKNESS OF DUST LAYER IN (MM/MIN)/INCREMENT
C
      LTHICK=(WT*VG*FLOAT(LSECT(NSECT))*6.0E+04)/(1.0E+03*A)
C
C
C  CALCULATE MMD AND WEIGHT COLLECTED FOR EACH INCREMENT
C
      ZTM=0.
      DO 2901 J=1,NS
      ZTM=ZTM+WS(J)
      CZA=ZTM/WT
      IF(CZA-0.5)2901,2901,2902
 2901 CONTINUE
 2902 CZB=(ZTM-WS(J))/WT
      TL1=CZA-CZB
      TL2=0.50-CZB
      KJ=J-1
      IF(KJ)2910,2910,2911
 2910 ZMD=DIAM(J)
      GO TO 2912
 2911 ZMD=DIAM(KJ)+(TL2/TL1)*(DIAM(J)-DIAM(KJ))
 2912 CONTINUE
      IF(NVI.EQ.2) ERAVG = SERAVG
      CALL PRTINC
 3000 CONTINUE
C
      ETC=(ZWT/VL)*100.
      IF(NVI.EQ.2) GO TO 1620
      DIFF=ETC-ETAO
      DIFF=ABS(DIFF)
      IF(DIFF-0.05)60,300,300
  300 CONTINUE
      WRITE(NPRNT,8656) ETAO,ETC
 8656 FORMAT(/' EST. EFFICIENCY =',F6.2,5X,'UNCORRECTED COMPUTED EFFICIE
     1NCY =',F6.2)
      IF(ITER.EQ.NITER) GO TO 60
      ETAO=ETC
      GO TO 305
   60 CONTINUE
      GO TO 1621
 1620 CONTINUE
      WRITE(NPRNT,1622) ETAO,ETC
 1622 FORMAT(/' DESIGN EFFICIENCY =',F6.2,5X,'UNCORRECTED COMPUTED EFFIC
     1IENCY =',F6.2)
 1621 CONTINUE
      ATOTAL=0.
      VG=0.
      DO 4985 I=1,NUMSEC
      ATOTAL=ATOTAL+AS(I)*9.3E-02
      VG=VG+(VGS(I)*4.73E-04)
 4985 CONTINUE
      VG=VG/FLOAT(NUMSEC)
      CALL PRTCHG
      CALL ADJUST
      GO TO 4000
 9999 STOP 11111
      END
PROG > 4K
```

```
      SUBROUTINE PRTINP
      REAL LINCS,NMS
      INTEGER VISKIP,VISAME
      DIMENSION IBLNK(21)
      COMMON/BLK1/DIAM(20),ONO(20),DXS(20),XMV(20),PCNT(20),RAD(20),
     1CCF(20),PRCU(21)
      COMMON/BLK2/LSECT(10),LINCS(10),PS(10)
      COMMON/BLK3/VG,ATOTAL,DD,ETAO,DL,PL,RHO
      COMMON/BLK5/ZMMDI,SIGMI,NONID,NRAPD,TDK,NUMSEC,NEFF,NTEMP,GFIT
      COMMON/BLK6/VOL(20),XNO(20),Q(20),WS(20),ITL(40),DW(45),AS(10),
     1VOS(10),TCS(10),WLS(10),ACS(10),BS(10),SYS(10),VGS(10),VGASS(10),
     2TEMPS(10),VISS(10),QSAT(20),U,F,EPSO,PI,ERAVG,BC,TEMP,EPS,VAVC,
     3OLDQ(20),OLDXNO(20),RFS(10),START1(10),START2(10),START3(10),
     4VSTAR(10)
      COMMON/BLK11/ENDPT(21),NENDPT
      COMMON/BLK12/ARD50(10),ARSIGM(10),ASNUCK(15),AZNUMS(15),AZIGGY(15)
      COMMON/BLK14/TMFP,NVI,NV1
      COMMON/BLK16/NCALC,NI,VRATIO,NF
      COMMON/BLK17/NREAD,NPRNT
      COMMON/BLK19/LK,DV,NN,NUMINC,NX,NY,NDATA,NEST,NDIST,NITER,IFINAL,
     1JI1,JI2,VISKIP,VISAME,US,FPATH,EBD,NDSET,NMS(10),D50,SIGMAP
      DATA IBLNK/21*' '/
      IF(LK) 111,111,160
  111 CONTINUE
      WRITE(NPRNT,5850)
 5850 FORMAT(40X,'*************************************')
      WRITE(NPRNT,5851)
 5851 FORMAT(40X,'*',35X,'*')
      WRITE(NPRNT,5852)
 5852 FORMAT(40X,'*',9X,'E.P.A. ESP MODEL',10X,'*')
      WRITE(NPRNT,5851)
      WRITE(NPRNT,5853)
 5853 FORMAT(40X,'*',4X,'I.E.R.L.-R.T.P. AND SO.R.I.',4X,'*')
      WRITE(NPRNT,5851)
      WRITE(NPRNT,5854)
 5854 FORMAT(40X,'*',7X,'REVISION II. AUG., 1979',5X,'*')
      WRITE(NPRNT,5851)
      WRITE(NPRNT,5850)
      NDSET=NDSET+1
      DLB=DL/2.29E-03
      PLB=PL/0.305
      RHOCGS=100.*RHO
      NCARD=0
      WRITE(NPRNT,2000) NDSET
 2000 FORMAT(//'  PRINTOUT OF INPUT DATA FOR DATA SET NUMBER ',I2//)
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
 2001 FORMAT(//'  DATA ON CARD NUMBER ',I3//)
      WRITE(NPRNT,1000) NENDPT,NDATA
 1000 FORMAT('  NENDPT = ',I2,2X,' NDATA = ',I2)
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1001) ITL
 1001 FORMAT(2X,40A2)
      GO TO(6000,6001,6002,6002),NDATA
 6000 CONTINUE
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1002) NEST,NDIST,NV1,NX,NY,NITER,NCALC,NRAPD,NEFF,
     1NTEMP,NONID
 1002 FORMAT('  NEST = ',I2,2X,'NDIST = ',I2,2X,'NVI = ',I2,2X,'NX = '
     1,I2,2X,'NY = ',I2,2X,'NITER = ',I2,2X,'NCALC = ',I2,2X,'NRAPD = ',
     2I2,2X,'NEFF = ',I2,2X,'NTEMP = ',I2,2X,'NONID = ',I2)
      IF(NCALC.NE.0) GO TO 1003
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1004) NN,NUMINC
 1004 FORMAT('  NN = ',I2,2X,'NUMINC = ',I2)
 1003 CONTINUE
      IF(NVI.EQ.1) GO TO 1005
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1006) IFINAL,JI1,JI2,VISKIP,VISAME
 1006 FORMAT('  IFINAL = ',I2,2X,'JI1 = ',I2,2X,'JI2 = ',I2,2X,'VISKIP =
     1',I2,2X,'VISAME = ',I2)
 1005 CONTINUE
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1007) DLS,PLS,ETAO,DD,EPS
 1007 FORMAT('  DL = ',F8.5,' GRN/ACF',2X,'PL = ',F8.4,' FT',2X,'ETAO =
     1',F8.5,' %',2X,'DD = ',F8.2,' KG/M**3',2X,'EPS = ',1PE10.3/)
      WRITE(NPRNT,1008) VRATIO,US,FPATH,EBD,RHOCGS
 1008 FORMAT('  VRATIO = ',F8.4,2X,'US = ',F8.6,' M**2/V-SEC',2X,'FPATH
     1= ',F8.4,2X,'EBD = ',F8.0,' V/M',2X,'RHOCGS = ',1PE9.2,' OHM-CM')
      IF(NRAPD.EQ.1) GO TO 1009
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1010) (I,ARD50(I),I,ARSIGM(I),I=2,NRAPD)
 1010 FORMAT('  ARD50(',I2,') = ',F4.1,' UM',2X,'ARSIGM(',I2,') = ',F4.1
     1/)
 1009 CONTINUE
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      DO 1011 I=1,NONID
      IF(I.EQ.7) NCARD=NCARD+1
      IF(I.EQ.7) WRITE(NPRNT,2001) NCARD
      IF(I.EQ.13) NCARD=NCARD+1
      IF(I.EQ.13) WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,6570) I,ASNUCK(I),I,AZIGGY(I),I,AZNUMS(I)
 6570 FORMAT('  ASNUCK(',I2,') = ',F4.2,2X,'AZIGGY(',I2,') = ',F4.2,2X,'
     1AZNUMS(',I2,') = ',F4.1/)
 1011 CONTINUE
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      NDCARD=2
      IF(NENDPT.LE.10) NDCARD=1
      IF(NENDPT.GT.20) NDCARD=3
      GO TO(1012,1013,1014),NDCARD
 1012 CONTINUE
      WRITE(NPRNT,1015) (IBLNK(I),I,ENDPT(I),I=1,NENDPT)
 1015 FORMAT(5(1X,A1,'ENDPT(',I2,') = ',F8.3,' UM',1X)/)
      GO TO 1016
 1013 CONTINUE
      WRITE(NPRNT,1015) (IBLNK(I),I,ENDPT(I),I=1,10)
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1015) (IBLNK(I),I,ENDPT(I),I=11,NENDPT)
      GO TO 1016
 1014 CONTINUE
      WRITE(NPRNT,1015) (IBLNK(I),I,ENDPT(I),I=1,10)
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1015) (IBLNK(I),I,ENDPT(I),I=11,20)
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1015) (IBLNK(I),I,ENDPT(I),I=21,NENDPT)
 1016 CONTINUE
 6001 CONTINUE
      IF(NDIST.EQ.1) GO TO 1017
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1018) D50,SIGMAP
 1018 FORMAT('  D50 = ',F8.4,' UM',2X,'SIGMAP = ',F8.4)
 1017 CONTINUE
      IF(NDIST.EQ.2) GO TO 1019
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      GO TO(1020,1021,1022),NDCARD
 1020 CONTINUE
      WRITE(NPRNT,1023) (IBLNK(I),I,PRCU(I),I=1,NENDPT)
 1023 FORMAT(5(1X,A1,'PRCU(',I2,') = ',F8.4,' %',1X)/)
      GO TO 1024
 1021 CONTINUE
      WRITE(NPRNT,1023) (IBLNK(I),I,PRCU(I),I=1,10)
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1023) (IBLNK(I),I,PRCU(I),I=11,NENDPT)
      GO TO 1024
 1022 CONTINUE
      WRITE(NPRNT,1023) (IBLNK(I),I,PRCU(I),I=1,10)
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1023) (IBLNK(I),I,PRCU(I),I=11,20)
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1023) (IBLNK(I),I,PRCU(I),I=21,NENDPT)
 1024 CONTINUE
 1019 CONTINUE
      IF(NDATA.GT.1) GO TO 5000
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      IF(NUMSEC.GT.5) GO TO 1026
      WRITE(NPRNT,1025) NUMSEC,(IBLNK(I),I,LSECT(I),I=1,NUMSEC)
 1025 FORMAT('  NUMSEC = ',I2,2X,5(1X,A1,'LSECT(',I2,') = ',I2))
      GO TO 1027
 1026 CONTINUE
      WRITE(NPRNT,1025) NUMSEC,(IBLNK(I),I,LSECT(I),I=1,5)
      WRITE(NPRNT,8570) (IBLNK(I),I,LSECT(I),I=6,NUMSEC)
 8570 FORMAT(/5(1X,A1,'LSECT(',I2,') = ',I2))
 1027 CONTINUE
      DO 1028 I=1,NUMSEC
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1029) I,AS(I),I,VOS(I),I,TCS(I),I,WLS(I)
 1029 FORMAT('  AS(',I2,') = ',1PE11.4,' FT**2',2X,'VOS(',I2,') = ',1PE1
     11.4,' V',2X,'TCS(',I2,') = ',1PE11.4,' A',2X,'WLS(',I2,') = ',1PE1
     21.4,' FT'/)
      WRITE(NPRNT,1030) I,ACS(I),I,BS(I),I,NWS(I)
 1030 FORMAT('  ACS(',I2,') = ',1PE11.4,' IN',2X,'BS(',I2,') = ',1PE11.4
     1,' IN',2X,'NWS(',I2,') = ',1PE11.4)
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      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1031) I,SYS(I),I,VGS(I),I,VGASS(I),I,TEMPS(I)
 1031 FORMAT('  SYS(',I2,') = ',1PE11.4,' IN',2X,'VGS(',I2,') = ',1PE11.
     14,' FT**3/MIN',2X,'VGASS(',I2,') = ',1PE11.4,' FT/SEC',2X,'TEMPS('
     2,I2,') = ',1PE11.4,' F'/)
      WRITE(NPRNT,1032) I,PS(I),I,VISS(I),I,LINCS(I)
 1032 FORMAT('  PS(',I2,') = ',1PE11.4,' ATM',2X,'VISS(',I2,') = ',1PE11
     1.4,' KG/M-SEC',2X,'LINCS(',I2,') = ',1PE11.4,' FT')
      IF(NVI.EQ.1) GO TO 1028
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      WRITE(NPRNT,1033) I,RFS(I),I,START1(I),I,START2(I)
 1033 FORMAT('  RFS(',I2,') = ',1PE11.4,2X,'START1(',I2,') = ',1PE11.4,'
     1 A/M**2',2X,'START2(',I2,') = ',1PE11.4,' A/M**2'/)
      WRITE(NPRNT,1034) I,START3(I),I,VSTAR(I)
 1034 FORMAT('  START3(',I2,') = ',1PE11.4,' A/M**2',2X,'VSTAR(',I2,') =
     1 ',1PE11.4,' V')
 1028 CONTINUE
      GO TO 5000
 6002 CONTINUE
      NCARD=NCARD+1
      WRITE(NPRNT,2001) NCARD
      DO 1035 I=1,NUMSEC
      IF(I.EQ.4) NCARD=NCARD+1
      IF(I.EQ.4) WRITE(NPRNT,2001) NCARD
      IF(I.EQ.7) NCARD=NCARD+1
      IF(I.EQ.7) WRITE(NPRNT,2001) NCARD
      IF(I.EQ.10) NCARD=NCARD+1
      IF(I.EQ.10) WRITE(NPRNT,2001) NCARD
      IF(NDATA.EQ.4) GO TO 1036
      WRITE(NPRNT,1037) I,VGS(I),I,VGASS(I)
 1037 FORMAT('  VGS(',I2,') = ',1PE11.4,' FT**3/MIN',2X,'VGASS(',I2,') =
     1 ',1PE11.4,' FT/SEC'/)
      GO TO 1035
 1036 CONTINUE
      WRITE(NPRNT,1038) I,VOS(I),I,TCS(I)
 1038 FORMAT('  VOS(',I2,') = ',1PE11.4,' V',2X,'TCS(',I2,') = ',1PE11.4
     1,' A'/)
 1035 CONTINUE
 5000 CONTINUE
      WRITE(NPRNT,1039)
 1039 FORMAT(1H1)
  160 CONTINUE
      RETURN
      END
      SUBROUTINE SPCHG1 (SW,ROVRI,OROVRI,XS,ETAPF,DW,QSAT,XNO,W,LSECT,
     1TC,VG,ETAO,FID,AFID,AVGFID,XCD,U,UEQ,I,NSECT,LINC,PL,CD,E,ERAVG,
     2NS,XPI)
      REAL LINC
      DIMENSION DW(45),QSAT(20),XNO(20),LSECT(10)
      IF(I.NE.1) GO TO 1286
      SW = 0.0
      ROVRI=10.
      OROVRI=20.0
C
C   COMPUTE VALUE OF EXPONENT IN DEUTSCH EQUATION FOR THE STATED EFF.
C
      XS=ALOG(100./(100.-ETAO))
C
 1286 CONTINUE
C
C   COMPUTE EFFICIENCY PER LENGTH INCREMENT
C
      ETAPF = 1.-EXP(-LINC*XS/PL)
C
C   COMPUTE AMOUNT OF MATERIAL REMOVED PER INCR.ON A TOTAL WEIGHT BASIS
C
      DW(I) = (W - SW) * ETAPF
      SW = SW + DW(I)
      FID=CD/(E*U*ERAVG)
      SUM=0.0
      DO 1300 L=1,NS
 1300 SUM=SUM+QSAT(L)*XNO(L)
      ZC=200.*(DW(I)/W)*(FLOAT(LSECT(NSECT))/TC)*VG*SUM
      ROVRI=ZC+1.0
      AFID=FID/ROVRI
      AVGFID=AFID*1.E-06
      XCD=CD*100000.
C
C   COMPUTE EFFECTIVE MOBILITY
C
      UEQ=U/ROVRI
C
      XPI=ETAPF*100.
      RETURN
      END
      SUBROUTINE SPCHG2 (NS,XNO,VIS,RAD,LINC.E.U.ERAVG.DNSION,
     1DELTNP,SUMMOB,PNUM,RHOP,TCHRG,PMOB,TDNSP.RDNSI.AFID,UEQ,AVGFID.
     2RIOVR,I,XS.ETAD,PL.ETAPF.CCF.XPI,OLDQ,Q,II,NSECT)
      REAL LINC
      DIMENSION XNO(20),RAD(20),CCF(20),OLDQ(20),Q(20)
      COMMON/BLK7/XDC(45,20)
      COMMON/BLK8/EAVG(30),CHFID(30)
      COMMON/BLK17/NREAD,NPRNT
      IF(I.NE.1) GO TO 1286
C
C   COMPUTE VALUE OF EXPONENT IN DEUTSCH EQUATION FOR THE DESIGN EFF.
C
      XS=ALOG(100./(100.-ETAD))
C
 1286 CONTINUE
C
C   COMPUTE EFFICIENCY PER LENGTH INCREMENT
C
      ETAPF = 1.-EXP(-LINC*XS/PL)
C
      DELTNP=0.
      SUMMOB=0.
      PNUM=0.
      RHOP=0.
      DO 1 J=1,NS
      TCHRG=XNO(J)*XDC(I,J)
      RHOP=RHOP+TCHRG
      SUMMOB=SUMMOB+(TCHRG*CCF(J))/(6.*3.14159*VIS*RAD(J))
      PNUM=PNUM+XNO(J)
      DIFF=XDC(I,J)
      IF((II.NE.1).OR.(I.NE.1)) DIFF=Q(J)-OLDQ(J)
      DELTNP=DELTNP+XNO(J)*DIFF
    1 CONTINUE
      PMOB=SUMMOB/PNUM
      TDNSP=RHOP/1.6E-19
      DNSION=CHFID(II)
      DELTNP=DELTNP/1.6E-19
      RDNSI=DNSION-DELTNP
      IF(RDNSI.GT.0.) GO TO 10
      PIR=DELTNP/DNSION
      RDNSI=0.
      WRITE(NPRNT,11) PIR,I,II
   11 FORMAT(1X,' A FACTOR OF ',F8.3,' MORE IONS NEEDED IN INCREMENT ',I
     12,', INTERVAL ',I2,' TO MEET CHARGING RATE')
   10 CONTINUE
      AFID=RDNSI
      AVGFID=AFID*1.E-06
      UEQ=(U*AFID*E+PMOB*RHOP)/(AFID*E+RHOP)
      RIOVR=(AFID*E)/(AFID*E+RHOP)
      XPI=ETAPF*100.
      RETURN
      END
      SUBROUTINE EFLD1 (UEQ,CD,AC,VO,SX,SY,NX,NY,TDK,P,AEPLT,VERGE,
     1CVERGE)
C  EVALUATION OF FIELDS, SPACE CHARGE DENSITY, POTENTIAL , AND
C  CURRENT DENSITY FOR A WIRE-PLATE PRECIPITATOR
      REAL MAXJ,MINJ,MOBILT(15,15)
      DIMENSION RHO(15,15),EX(15,15),OLDRO(15,15),OLDV(15,15),
     1CDNSTY(15,15),V(15,15),EY(15,15)
      COMMON /BLK13/VCOOP(15,15),NVIT
      COMMON/BLK17/NREAD,NPRNT
      DATA RHO/225*0./,V/225*0./,EX/225*0./,EY/225*0./,OLDRO/225*0./,
     1OLDV/225*0./,CDNSTY/225*0./,MOBILT/225*0./
      VO=-1.*VO
      PI=3.1416
      EPS0=8.854E-12
      RO = AC
      ROC = 100.0*RO
      RF = 1.0
      RELD = (293.0/TDK)*(P/1.0)
      EORO = ROC*RF*(30.0*RELD + 9.0*SQRT(RELD/ROC))*1.0E03
C
C   COMPUTE INITIAL ESTIMATE OF SPACE CHARGE DENSITY AT WIRE
C
      VERGE=(-2.*CD*(1.01 + 0.99)*SY)/(2.*PI*UEQ*EORO)
C
      QZERO=VERGE
      DO 550 I=1,NX
      DO 550 J=1,NY
      MOBILT(I,J)=UEQ
  550 CONTINUE
      MAXJ=CD*1.01
      MINJ=CD*0.99
      NX1=NX-1
      NY1=NY-1
      AX=SX/NX1
      AY=SY/NY1
      AXS=AX*AX
      AYS=AY*AY
      ASP=(AXS*AYS)/EPS0
      ASS=1./(2.*(AXS+AYS))
      Z=0.
      DO 4615 I=1,NX
      DO 4615 J=1,NY
 4615 V(I,J)=VCOOP(I,J)
    1 Z=Z+1.
      IZ=Z
      IF(Z.EQ.25) WRITE(NPRNT,1865)
 1865 FORMAT(1X,' CONVERGENCE ON CURRENT DENSITY CAN NOT BE OBTAINED IN
     125 ITERATIONS')
      IF(Z.EQ.25.) GO TO 700
      LL=0
  300 LL=LL+1
      RHO(1,1)=QZERO
      EX(1,1)=0.0
      EY(1,1)=0.0
      DO 201 I=2,NX
      EY(I,1)=0.
      EX(I,1)=(V(I-1,1)-V(I,1))/AX
      Q1=2.*MOBILT(I,1)
      Q2=Q1*AX
      Q3=Q1*AY
      Q4=Q2*AY
      Q5=-EPS0*EX(I,1)*(Q3-AY*MOBILT(I-1,1))
      Q6=Q5*Q5
      Q7=Q1*Q4*EPS0*AY*EX(I,1)*RHO(I-1,1)
      Q8=-SQRT(Q6+Q7)
      RHO(I,1)=(Q5+Q8)/Q4
  201 CONTINUE
      DO 203 J=2,NY
      EX(1,J)=0.
      EY(1,J)=(V(1,J-1)-V(1,J))/AY
      P1=2.*MOBILT(1,J)
      P2=P1*AX
      P3=P1*AY
      P4=P2*AY
      P5=-EPS0*EY(1,J)*(P2-AX*MOBILT(1,J-1))
      P6=P5*P5
      P7=P1*P4*EPS0*AX*EY(1,J)*RHO(1,J-1)
      P8=-SQRT(P6+P7)
      RHO(1,J)=(P5+P8)/P4
  203 CONTINUE
      DO 202 I=2,NX
      EY(I,NY)=0.
      EX(I,NY)=(V(I-1,NY)-V(I,NY))/AX
      R1=2.*MOBILT(I,NY)
      R2=R1*AX
      R3=R1*AY
      R4=R2*AY
      R5=-EPS0*EX(I,NY)*(R3-AY*MOBILT(I-1,NY))
      R6=R5*R5
      R7=R1*R4*EPS0*AY*EX(I,NY)*RHO(I-1,NY)
      R8=-SQRT(R6+R7)
      RHO(I,NY)=(R5+R8)/R4
  202 CONTINUE
      DO 307 I=2,NX
      DO 307 J=2,NY1
  313 EX(I,J)=(-1.)*(V(I,J)-V(I-1,J))/AX
      EY(I,J)=(-1.)*(V(I,J)-V(I,J-1))/AY
      D1=2.*MOBILT(I,J)
      D2=D1*AX
      D3=D1*AY
      D4=D2*AY
      D5=-EPS0*(EX(I,J)*(D3-AY*MOBILT(I-1,J))+EY(I,J)*(D2-AX*MOBILT(I,J-
     11)))
      D6=D5*D5
      D7=D1*D4*EPS0*(AY*EX(I,J)*RHO(I-1,J)+AX*EY(I,J)*RHO(I,J-1))
      D8=-SQRT(D6+D7)
      RHO(I,J)=(D5+D8)/D4
  307 CONTINUE
      DO 301 I=1,NX1
      DO 301 J=1,NY
      OLDV(I,J)=V(I,J)
      OLDRO(I,J)=RHO(I,J)
      IF(I.EQ.1.AND.J.EQ.1) GO TO 301
      IF(I.EQ.1.AND.J.NE.1) GO TO 304
      IF(I.NE.1.AND.J.EQ.1) GO TO 305
      IF(J.EQ.NY) GO TO 600
      GO TO 306
  600 V(I,NY)=ASS*(AYS*(V(I-1,NY)+V(I+1,NY))+2.*AXS*V(I,NY-1)+ASP*RHO(I,
     1NY))
      GO TO 301
  304 IF(I.EQ.1.AND.J.EQ.NY)  GO TO 350
      V(1,J)=ABS*(2.*AYS*V(2,J)+AXS*(V(1,J+1)+V(1,J-1))+ASP*RHO(1,J))
      GO TO 301
  350 V(1,NY)=ABS*(2.*AYS*V(2,NY)+2.*AXS*V(1,NY-1)+ASP*RHO(1,NY))
      GO TO 301
  305 V(I,1)=ABS*(AYS*(V(I+1,1)+V(I-1,1))+2.*AXS*V(I,2)+ASP*RHO(I,1))
      GO TO 301
  306 V(I,J)=ABS*(AYS*(V(I+1,J)+V(I-1,J))+AXS*(V(I,J-1)+V(I,J+1))+ASP*RH
     1O(I,J))
  301 CONTINUE
      IF(LL.EQ.2000) WRITE(NPRNT,1866)
 1866 FORMAT(1X,' CONVERGENCE ON POTENTIAL GRID CAN NOT BE OBTAINED IN 2
     1000 ITERATIONS')
      IF(LL.EQ.2000) GO TO 700
      DO 320 I=1,NX1
      DO 320 J=1,NY1
      IF(ABS(V(I,J)-OLDV(I,J)).LT.1.) GO TO 320
      GO TO 300
  320 CONTINUE
      CDNSTY(NX,1)=EX(NX,1)*MOBILT(NX,1)*RHO(NX,1)
      ACDNTY=CDNSTY(NX,1)
  950 DO 900 J=2,NY
      CDNSTY(NX,J)=EX(NX,J)*MOBILT(NX,J)*RHO(NX,J)
      ACDNTY=ACDNTY+CDNSTY(NX,J)
  900 CONTINUE
      ACDNTY=ACDNTY/NY
      IF(ACDNTY.GT.MAXJ) GO TO 910
      IF(ACDNTY.LT.MINJ) GO TO 920
      GO TO 980
 910  QZERO=MINJ/ACDNTY*QZERO
      GO TO 1
 920  QZERO=MAXJ/ACDNTY*QZERO
      GO TO 1
  980 EPLT=EX(NX,1)
      DO 1000 J=2,NY
      EPLT=EPLT+EX(NX,J)
 1000 CONTINUE
      AEPLT=EPLT/NY
 700  CONTINUE
      CVERGE=QZERO
      VO=-1.*VO
      RETURN
      END
PROG > 4K
```

```
      SUBROUTINE EFLD2 (UEQ,AC,VO,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINAL,VSTART,VW,ACDNTY,NWIRE,NEC,EBD,JI1,JI2)
C  EVALUATION OF FIELDS, SPACE CHARGE DENSITY, POTENTIAL , AND
C  CURRENT DENSITY FOR A WIRE-PLATE PRECIPITATOR
      REAL MAXJ,MINJ,MOBILT(15,15),NWIRE,MAXS
      DIMENSION RHO(15,15),EX(15,15),OLDRO(15,15),OLDV(15,15),
     1CDNSTY(15,15),V(15,15),EY(15,15),EAVGS(30),CHFIDS(30),ECOLLS(30)
      COMMON/BLK8/EAVG(30),CHFID(30)
      COMMON/BLK9/ECOLL(30)
      COMMON /BLK13/VCOOP(15,15),NVII
      COMMON/BLK17/NREAD,NPRNT
      DATA RHO/225*0./,V/225*0./,EX/225*0./,EY/225*0./,OLDRO/225*0./,
     1OLDV/225*0./,CDNSTY/225*0./,MOBILT/225*0./
      IVCK=0
      VO=-1.*VO
      VW=-1.*VSTART
      RO=AC
      RELD=(293./TDK)*(P/1.)
      ROC=100.*RO
      EORO=ROC*RF*(30.*RELD+9.*SQRT(RELD/ROC))*1.E+03
      DO 550 I=1,NX
      DO 550 J=1,NY
      MOBILT(I.J)=UEQ
  550 CONTINUE
      PI=3.1416
      EPSO=8.854E-12
      SSTART=START
      MINJ=0.
      MAXS=0.
      NX1=NX-1
      NY1=NY-1
      AX=SX/NX1
      AY=SY/NY1
      AXS=AX*AX
      AYS=AY*AY
      ASP=(AXS*AYS)/EPSO
      ASS=1./(2.*(AXS+AYS))
      DO 1001 II=1,IFINAL
      IF(II.EQ.JI1) START=DSTART
      IF(II.GE.JI2) START=CSTART
      MAXS=MAXS+START
 1526 CONTINUE
      MAXJ=MAXS*1.01
      MINJ=MAXS*.99
      QZERO=-(2.*(MAXJ+MINJ)*SY*1.E-03)/(2.*PI*UEQ*ROC*RF*(30.*RELD+9.*
     1SQRT(RELD/ROC)))
      CALL CHAN(VW,NX,NY,SX,SY,PI,AC,NWIRE)
      Z=0
      DO 4615 I=1,NX
      DO 4615 J=1,NY
 4615 V(I,J)=VCOOP(I.J)
    1 Z=Z+1
      IZ=Z
      IF(Z.EQ.25) WRITE(NPRNT,1865)
 1865 FORMAT(1X,' CONVERGENCE ON CURRENT DENSITY CAN NOT BE OBTAINED IN
     125 ITERATIONS')
      IF(Z.EQ.25) GO TO 700
      LL=0
  300 LL=LL+1
      RHO(1,1)=QZERO
      V(1,1)=VW
      EX(1,1)=0.0
      EY(1,1)=0.0
      DO 201 I=2,NX
      EY(I,1)=0.
      EX(I,1)=(V(I-1,1)-V(I,1))/AX
      Q1=2.*MOBILT(I,1)
      Q2=Q1*AX
      Q3=Q1*AY
      Q4=Q2*AY
      Q5=-EPS0*EX(I,1)*(Q3-AY*MOBILT(I-1,1))
      Q6=Q5*Q5
      Q7=Q1*Q4*EPS0*AY*EX(I,1)*RHO(I-1,1)
      Q7=ABS(Q7)
      Q8=-SQRT(Q6+Q7)
      RHO(I,1)=(Q5+Q8)/Q4
  201 CONTINUE
      DO 203 J=2,NY
      EX(1,J)=0.
      EY(1,J)=(V(1,J-1)-V(1,J))/AY
      P1=2.*MOBILT(1,J)
      P2=P1*AX
      P3=P1*AY
      P4=P2*AY
      P5=-EPS0*EY(1,J)*(P2-AX*MOBILT(1,J-1))
      P6=P5*P5
      P7=P1*P4*EPS0*AX*EY(1,J)*RHO(1,J-1)
      P7=ABS(P7)
      P8=-SQRT(P6+P7)
      RHO(1,J)=(P5+P8)/P4
  203 CONTINUE
      DO 202 I=2,NX
      EY(I,NY)=0.
      EX(I,NY)=(V(I-1,NY)-V(I,NY))/AX
      R1=2.*MOBILT(I,NY)
      R2=R1*AX
      R3=R1*AY
      R4=R2*AY
      R5=-EPS0*EX(I,NY)*(R3-AY*MOBILT(I-1,NY))
      R6=R5*R5
      R7=R1*R4*EPS0*AY*EX(I,NY)*RHO(I-1,NY)
      R7=ABS(R7)
      R8=-SQRT(R6+R7)
      RHO(I,NY)=(R5+R8)/R4
  202 CONTINUE
      DO 307 I=2,NX
      DO 307 J=2,NY1
  313 EX(I,J)=(-1.)*(V(I,J)-V(I-1,J))/AX
      EY(I,J)=(-1.)*(V(I,J)-V(I,J-1))/AY
      D1=2.*MOBILT(I,J)
      D2=D1*AX
      D3=D1*AY
      D4=D2*AY
      D5=-EPS0*(EX(I,J)*(D3-AY*MOBILT(I-1,J))+EY(I,J)*(D2-AX*MOBILT(I,J-
     11)))
      D6=D5*D5
      D7=D1*D4*EPS0*(AY*EX(I,J)*RHO(I-1,J)+AX*EY(I,J)*RHO(I,J-1))
      D7=ABS(D7)
      D8=-SQRT(D6+D7)
      RHO(I,J)=(D5+D8)/D4
  307 CONTINUE
      DO 301 I=1,NX1
      DO 301 J=1,NY
      OLDV(I,J)=V(I,J)
      OLDRO(I,J)=RHO(I,J)
      IF(I.EQ.1.AND.J.EQ.1) GO TO 301
      IF(I.EQ.1.AND.J.NE.1) GO TO 304
      IF(I.NE.1.AND.J.EQ.1) GO TO 305
      IF(J.EQ.NY) GO TO 600
      GO TO 306
  600 V(I,NY)=ASS*(AYS*(V(I-1,NY)+V(I+1,NY))+2.*AXS*V(I,NY-1)+ASP*RHO(I,
     1NY))
      GO TO 301
  304 IF(I.EQ.1.AND.J.EQ.NY)  GO TO 350
      V(1,J)=ASS*(2.*AYS*V(2,J)+AXS*(V(1,J+1)+V(1,J-1))+ASP*RHO(1,J))
      GO TO 301
  350 V(1,NY)=ASS*(2.*AYS*V(2,NY)+2.*AXS*V(1,NY-1)+ASP*RHO(1,NY))
      GO TO 301
  305 V(I,1)=ASS*(AYS*(V(I+1,1)+V(I-1,1))+2.*AXS*V(I,2)+ASP*RHO(I,1))
      GO TO 301
  306 V(I,J)=ASS*(AYS*(V(I+1,J)+V(I-1,J))+AXS*(V(I,J-1)+V(I,J+1))+ASP*RH
     1O(I,J))
  301 CONTINUE
      IF(LL.EQ.2000) WRITE(NPRNT,1866)
 1866 FORMAT(1X,' CONVERGENCE ON POTENTIAL GRID CAN NOT BE OBTAINED IN 2
     1000 ITERATIONS')
      IF(LL.EQ.2000) GO TO 700
      DO 320 I=1,NX1
      DO 320 J=1,NY
      IF(ABS(V(I,J)-OLDV(I,J)).LT.1.) GO TO 320
      GO TO 300
  320 CONTINUE
      CDNSTY(NX,1)=EX(NX,1)*MOBILT(NX,1)*RHO(NX,1)
      ACDNTY=CDNSTY(NX,1)
  950 DO 900 J=2,NY
      CDNSTY(NX,J)=EX(NX,J)*MOBILT(NX,J)*RHO(NX,J)
      ACDNTY=ACDNTY+CDNSTY(NX,J)
  900 CONTINUE
      ACDNTY=ACDNTY/NY
      IF(ACDNTY.GT.MAXJ) GO TO 910
      IF(ACDNTY.LT.MINJ) GO TO 920
      GO TO 980
  910 VW=VW+1.*VW*(MAXJ-ACDNTY)/MAXJ
      GO TO 1000
  920 VW=VW+1.*VW*(MINJ-ACDNTY)/MINJ
 1000 CONTINUE
      TEST=ABS(ACDNTY-(MAXJ+MINJ)/2.)
      TEST1=0.01*ACDNTY
      IF(TEST.LT.TEST1) GO TO 980
      GO TO 1
  980 CONTINUE
      EPLT=EX(NX,1)
      DO 1200 J=2,NY
      EPLT=EPLT+EX(NX,J)
 1200 CONTINUE
      AEPLT=EPLT/NY
 700  CONTINUE
      WRITE(NPRNT,8888) VW,ACDNTY,AEPLT
 8888 FORMAT(38X,'VW = ',1PE11.4,2X,'ACDNTY = ',1PE11.4,2X,'AEPLT = ',1P
     1E11.4//)
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```
      IF(ABS(EX(NX,1)).LT.EBD) GO TO 1480
      WRITE(NPRNT,1481) VW,ACDNTY
 1481 FORMAT(' THE BREAKDOWN FIELD NEAR THE PLATE IS EXCEEDED AT VW =',E
     111.4,1X,'AND ACDNTY =',E11.4)
      GO TO 1525
 1480 CONTINUE
      IF(IVCK.EQ.1) GO TO 1525
      IF(ABS(VW).EQ.ABS(VO)) GO TO 1525
      IF(ABS(VW).GT.ABS(VO)) GO TO 1523
      OLDVW=VW
      OLDCD=ACDNTY
      GO TO 1524
 1523 CONTINUE
      MAXS=ACDNTY-((ACDNTY-OLDCD)/(VW-OLDVW))*(VW-VO)
      VW=OLDVW
      IVCK=1
      GO TO 1526
 1524 CONTINUE
 1001 CONTINUE
 1525 CONTINUE
      IF(NEC.NE.0) GO TO 3000
      K=1
      DO 3001 J=1,NY1
      RSUM=0.
      ESUM=0.
      DO 3002 I=1,NX
      IF(J.EQ.1) GO TO 3005
      ESUM=ESUM+(SQRT(EX(I,J)**2+EY(I,J)**2)+SQRT(EX(I,J+1)**2+
     1EY(I,J+1)**2))/(2.*NX)
      GO TO 3006
 3005 CONTINUE
      ESUM=ESUM+SQRT(EX(I,J+1)**2+FY(I,J+1)**2)/(2.*NX)
      IF(I.EQ.NX) ESUM=ESUM-VO/(2.*SX)
 3006 CONTINUE
      RSUM=RSUM-(RHO(I,J)+RHO(I,J+1))/(2.*1.6E-19*NX)
 3002 CONTINUE
      FAVGS(K)=ESUM
      CHFIDS(K)=RSUM
      K=K+1
 3001 CONTINUE
      NYY=NY1
      DO 3003 L=1,NY1
      EAVG(L)=EAVGS(NYY)
      CHFID(L)=CHFIDS(NYY)
      NYY=NYY-1
 3003 CONTINUE
      KK=1
      M1=NY1+1
      M2=2*NY1
      DO 3004 M=M1,M2
      EAVG(M)=EAVGS(KK)
      CHFID(M)=CHFIDS(KK)
      KK=KK+1
 3004 CONTINUE
 3000 CONTINUE
      LL=1
      DO 3007 NN=1,NY1
      ECOLLS(LL)=-(EX(NX,NN)+EX(NX,NN+1))/2.
      LL=LL+1
 3007 CONTINUE
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      L1=NY1
      DO 3008 L=1,NY1
      ECOLL(L)=ECOLL8(L1)
      L1=L1-1
 3008 CONTINUE
      L2=1
      I1=NY1+1
      I2=2*NY1
      DO 3009 I=I1,I2
      ECOLL(I)=ECOLL8(L2)
      L2=L2+1
 3009 CONTINUE
      VO=-1.*VO
      START=SSTART
      RETURN
      END
 PROG > 4K
```

```
       SUBROUTINE CHARGN (ECHARG,SCHARG,NUMINC,CONST,EZERO,V,RSIZE,ECONST
      *,CMKS,RR,FCONST,FACTOR,COEFF,AFID,RATE,H,XI,YI,NN,X,Y)
       H2=H/2.
       Y=YI
       X=XI
       DO 2 I=1,NN
       T1=H*RATE(ECHARG,SCHARG,NUMINC,CONST,EZERO,V,RSIZE,ECONST,CMKS,RR,
      *FCONST,FACTOR,COEFF,AFID,X,Y)
       T2=H*RATE(ECHARG,SCHARG,NUMINC,CONST,EZERO,V,RSIZE,ECONST,CMKS,RR,
      *FCONST,FACTOR,COEFF,AFID,X+H2,Y+T1/2.)
       T3=H*RATE(ECHARG,SCHARG,NUMINC,CONST,EZERO,V,RSIZE,ECONST,CMKS,RR,
      *FCONST,FACTOR,COEFF,AFID,X+H2,Y+T2/2.)
       T4=H*RATE(ECHARG,SCHARG,NUMINC,CONST,EZERO,V,RSIZE,ECONST,CMKS,RR,
      *FCONST,FACTOR,COEFF,AFID,X+H,Y+T3)
       Y=Y+(T1+2.*T2+2.*T3+T4)/6.
       X=X+H
     2 CONTINUE
       RETURN
       END
      FUNCTION RATE (ECHARG,SCHARG,NUMINC,CONST,EZERO,V,RSIZE,ECONST,
     *CMKS,RR,FCONST,FACTOR,COEFF,AFID,NTIME,NUMBER)
      REAL INTGRL,NE,NUMBER,NTIME
      DIMENSION T(3),A(3)
      DATA T/-0.77459667,0.0,0.77459667/
      DATA A/0.55555556,0.88888889,0.55555556/
      NE=-NUMBER*ECHARG
      PI=3.1415927
      IF(NUMBER-SCHARG)7005,7006,7006
 7005 CALL ARCCOS(NUMBER,SCHARG,THZERO)
      IF(THZERO.LE.1.E-05) GO TO 7006
      IF(1.57-THZERO) 7011,7011,7015
 7015 CONTINUE
      GO TO 7007
 7006 THZERO=0.
 7007 YFUC=0.0
      DO 7002 I=1,3
      THETA=T(I)*(PI-2.*THZERO)/4.+(PI+2.*THZERO)/4.
      CTHETA=COS(THETA)
      TCONST=CONST*CTHETA
      ECOS=EZERO*CTHETA
      C1=-NE/(CMKS*ECOS)
      CO=TCONST/(2.*ECOS)
      CALL ZERO(C1,CO,RZERO)
      ARG1=-(NUMBER*V*(RZERO-RSIZE)/RZERO+(ECONST-RR*RZERO+FCONST/RZERO*
     1*2)*CTHETA)
      IF(ABS(ARG1).GT.30.0) GO TO 7025
      YVAL=EXP(ARG1)*SIN(THETA)
      GO TO 7026
 7025 YVAL=0.
 7026 CONTINUE
      YFUC=YFUC+A(I)*YVAL
 7002 CONTINUE
      RATE1=(PI-2.*THZERO)/4.*YFUC*FACTOR*AFID
      GO TO 7012
 7011 RATE1=0.
 7012 CONTINUE
      ARG3=-V*NUMBER
      IF(ABS(ARG3).GT.30.0) GO TO 7031
      RATE2=FACTOR*EXP(ARG3)*AFID
      GO TO 7032
 7031 RATE2=0.
 7032 CONTINUE
      IF(NUMBER-SCHARG)7008,7009,7009
 7008 RATE3=COEFF*(1.-NUMBER/SCHARG)**2*AFID
      GO TO 7010
 7009 RATE3=0.
 7010 CONTINUE
      RATE=RATE1+RATE2+RATE3
      RETURN
      END
      SUBROUTINE ARCCOS (A,B,ACOS)
      RATIO=A/B
      T=1.
      SUM=0.
      TERM=RATIO
    1 U=2.*T-1.
      V=2.*T
      W=2.*T+1.
      TERM=TERM/V*U**2/W*RATIO**2
      SUM=SUM+TERM
      T=T+1.
      IF(TERM-5.E-05)3,3,1
    3 ACOS=1.5707963-SUM-RATIO
      RETURN
      END
      SUBROUTINE ZERO (C1,CO,RZERO)
      B=SQRT((27.*CO*CO)/(C1*C1*C1))
      CALL ARCCOS(B,1.,C)
      D=-2.*SQRT(C1/3.)
      RZERO=D*COS((C+6.28318)/3.)
      RETURN
      END
      SUBROUTINE CHGSUM
      REAL LINC,LTHICK,JPART,JION
      COMMON/BLK5/ZMMDI,SIGMI,NONID,MRAPD,TDK,NUMSEC,NEFF,NTEMP,GFIT
      COMMON/BLK6/VOL(20),XNO(20),Q(20),WS(20),ITL(40),DM(45),AS(10),
     1VDS(10),TCS(10),WLS(10),ACS(10),BS(10),SVS(10),VGS(10),VGASS(10),
     2TEMPS(10),VISS(10),QSAT(20),U,E,EPSO,PI,ERAVG,BC,TEMP,EPS,VAVC,
     3OLDQ(20),OLDXNO(20),RFS(10),START1(10),START2(10),START3(10),
     4VSTAR(10)
      COMMON/BLK14/TMFP,NVI,NV1
      COMMON/BLK15/NPRINT,NSECT,SLNGTH,A,VO,TC,B,AC,WL,CL,CD,ET,SY,
     1VGAS,P,VIS,W,LINC,XPI,RIOVR,EPLT,AFID,XCD,ZMD,
     2WT,LTHICK,JPART,JION,I,ROVRI
      COMMON/BLK20/SCHARG,CHRFID,TIMEI,TIMEF,V,FACTRE,RSIZE,CNUMBR,J,II,
     1ITER,OLDQF(20),OLDQT(20),SOLDQF(20),SOLDQT(20)
      IF(NVI.EQ.1) GO TO 50
      IF((I.EQ.1).AND.(II.EQ.1)) GO TO 51
      GO TO 52
   51 CONTINUE
      OLDQF(J)=0.
      OLDQT(J)=0.
   52 CONTINUE
      IF(ITER.NE.1) GO TO 53
      IF(II.GT.1) GO TO 50
      SOLDQF(J)=OLDQF(J)
      SOLDQT(J)=OLDQT(J)
   53 CONTINUE
      IF((ITER.GT.1).AND.(II.EQ.1)) GO TO 54
      GO TO 55
   54 CONTINUE
      OLDQF(J)=SOLDQF(J)
      OLDQT(J)=SOLDQT(J)
   55 CONTINUE
   50 CONTINUE
      IF(NVI.EQ.2) GO TO 56
      IF(I.GT.1) GO TO 56
      OLDQF(J)=0.
      OLDQT(J)=0.
   56 CONTINUE
      SATCHG=E*SCHARG
      IF(OLDQF(J).GE.SATCHG) GO TO 1
      CF1=((CHRFID*U*E)/(4.*EPSO))*(TIMEF-TIMEI)
      CF2=1./(1.-OLDQF(J)/SATCHG)
      QF=SATCHG*((CF1+CF2-1.)/(CF1+CF2))
      IF(QF.GT.SATCHG) QF=SATCHG
      GO TO 2
    1 CONTINUE
      QF=OLDQF(J)
    2 CONTINUE
      OLDQF(J)=QF
      ARG=(V*OLDQT(J))/E
      IF(ARG.GT.30.) GO TO 10
      QT=(E/V)*ALOG(((E**2*RSIZE*VAVC*CHRFID)/(4.*EPSO*BC*TDK))*(TIMEF-
     1TIMEI)+EXP(ARG))
      OLDQT(J)=QT
      GO TO 9
   10 CONTINUE
      QT=OLDQT(J)
    9 CONTINUE
      CNUMBR=(QF+QT)/E
      RETURN
      SUBROUTINE PRTINC
      REAL LINC,LTHICK,JPART,JION
      COMMON/BLK3/VG,ATOTAL,DD,ETAO,DL,PL,RHO
      COMMON/BLK5/ZMMDI,SIGMI,NONID,NRAPD,TDK,NUMSEC,NEFF,NTEMP,GFIT
      COMMON/BLK6/VOL(20),XNO(20),S(20),WS(20),ITL(40),DW(45),AS(10),
     1VOS(10),TCS(10),WLS(10),ACS(10),BS(10),SYS(10),VGS(10),VGASS(10),
     2TEMPS(10),VISS(10),QSAT(20),U,E,EPSO,PI,ERAVG,BC,TEMP,EPS,VAVC,
     3OLDQ(20),OLDXNO(20),RFS(10),START1(10),START2(10),START3(10),
     4VSTAR(10)
      COMMON/BLK14/TMFP,NVI,NV1
      COMMON/BLK15/NPRINT,NSECT,SLNGTH,A,VO,TC,B,AC,WL,CL,CD,ET,SY,
     1VGAS,P,VIS,W,LINC,XPI,RIOVR,EPLT,AFID,XCD,ZMD,
     2WT,LTHICK,JPART,JION,I,ROVRI
      COMMON/BLK17/NREAD,NPRNT
      IF(NPRINT.NE.1) GO TO 8439
      IF(NSECT.GT.1) GO TO 1585
      WRITE(NPRNT,6550)
 6550 FORMAT(//' INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE'//)
      WRITE(NPRNT,3010) ITL
 3010 FORMAT('0',40A2/)
 1585 CONTINUE
      NPRINT=0
      WRITE(NPRNT,7820) NSECT,SLNGTH
 7820 FORMAT(/' CALCULATION IS IN SECTION NO. =',I2,' AND THE SECTION LE
     1NGTH IS =',F8.4,' M')
      WRITE(NPRNT,7715) A,VO,TC
 7715 FORMAT(/' COLLECTION AREA =',1PE11.3,' M2',T41,'APPLIED VOLTAGE ='
     1,E11.3,' VOLTS',7X,'TOTAL CURRENT =',E11.3,' AMPS')
      WRITE(NPRNT,7716) B,AC,WL
 7716 FORMAT(' WIRE TO PLATE =',1PE11.3,' M',T41,'CORONA WIRE RADIUS =',
     1E11.3,' M',8X,'CORONA WIRE LENGTH =',E11.3,' M')
      WRITE(NPRNT,7717) CL,CD,ET
 7717 FORMAT(' CURRENT/M =',1PE11.3,' AMP/M',T41,'CURRENT DENSITY =',E11
     1.3,' AMP/M2',6X,'DEPOSIT E FIELD =',E11.3,' VOLT/M')
      WRITE(NPRNT,7718) SY,VG,VGAS
 7718 FORMAT(' 1/2 WIRE TO WIRE =',1PE11.3,' M',T41,'GAS FLOW RATE =',E1
     11.3,' M3/SEC',8X,'GAS VELOCITY =',E11.3,' M/SEC')
      WRITE(NPRNT,7731) TDK,P,VIS
 7731 FORMAT(' TEMPERATURE =',F8.3,' K',T41,'PRESSURE =',F8.3,' ATM',19X
     1,'VISCOSITY =',1PE11.3,' KG/M-SEC')
      WRITE(NPRNT,7732) U,VAVC,TMFP
 7732 FORMAT(' ION MOBILITY =',1PE11.3,' M2/VOLT-SEC',T41,'MEAN THERMAL
     1SPEED =',E11.3,' M/SEC',4X,'PART. PATH PARAM. =',E11.3,' M')
      WRITE(NPRNT,7733) W,LINC,XPI
 7733 FORMAT(' DUST WEIGHT =',1PE11.3,' KG/SEC',T41,'LENGTH INCR. =',0PF
     110.8,' M',15X,'INPUT EFF./INCR. =',F6.2)
      IF(NVI.EQ.1) GO TO 4689
      WRITE(NPRNT,4322)
 4322 FORMAT(//T2,'RIOVR',5X,'ERAVG',8X,'EPLT',8X,'AFID',6X,'CMCD',6X,'M
     1MD',8X,'WEIGHT',4X,'DUST LAYER',3X,'J(PART)',6X,'J(ION)',3X,'INCR.
     2 NO.'/)
      GO TO 4690
 4689 CONTINUE
      WRITE(NPRNT,4333)
 4333 FORMAT(//T2,'ROVRI',5X,'ERAVG',8X,'EPLT',8X,'AFID',6X,'CMCD',6X,'M
     1MD',8X,'WEIGHT',4X,'DUST LAYER',3X,'J(PART)',6X,'J(ION)',3X,'INCR.
     2 NO.'/)
 4690 CONTINUE
 8439 CONTINUE
      IF(NVI.EQ.1) GO TO 4691
      WRITE(NPRNT,4323) RIOVR,ERAVG,EPLT,AFID,XCD,ZMD,WT,LTHICK,
     1JPART,JION,I
 4323 FORMAT(T2,F6.4,1X,1PE11.3,1X,E11.4,1X,E11.4,1X,0PF7.1,1X,1PE10.2,1
     1X,E11.3,1X,E11.3,1X,E10.2,2X,E10.2,6X,I2)
      GO TO 3000
 4691 CONTINUE
      WRITE(NPRNT,4334) ROVRI,ERAVG,EPLT,AFID,XCD,ZMD,WT,LTHICK,
     1JPART,JION,I
 4334 FORMAT(T2,F6.4,1X,1PE11.3,1X,E11.4,1X,E11.4,1X,0PF7.1,1X,1PE10.2,1
     1X,E11.3,1X,E11.3,1X,E10.2,2X,E10.2,6X,I2)
 3000 CONTINUE
      RETURN
      END
      SUBROUTINE PRTCHG
      REAL NWS
      INTEGER VISKIP.VISAME
      DIMENSION YY(20)
      COMMON/BLK1/DIAM(20),ONO(20),DXS(20),XMV(20),PCNT(20),RAD(20),
     1CCF(20),PRCU(21)
      COMMON/BLK4/NS
      COMMON/BLK6/VOL(20),XNO(20),Q(20),WS(20),ITL(40),DM(45),AS(10).
     1VOS(10),TCS(10),WLS(10),ACS(10),BS(10),SYS(10),VGS(10),VGASS(10).
     2TEMPS(10),VISS(10),QSAT(20),U,E,EPSO,PI,ERAVG,BC,TEMP,EPS,VAVC,
     3OLDQ(20),OLDXNO(20),RFS(10),START1(10),START2(10),START3(10),
     4VSTAR(10)
      COMMON/BLK7/XDC(45,20)
      COMMON/BLK8/EAVG(30),CHFID(30)
      COMMON/BLK14/TMFP,NVI,NV1
      COMMON/BLK16/NCALC,NI,VRATIO,NF
      COMMON/BLK17/NREAD,NPRNT
      COMMON/BLK19/LK,DV,NN,NUMINC,NX,NY,NDATA,NEST,NDIST,NITER,IFINAL,
     1JI1,JI2,VISKIP.VISAME,US,FPATH.EBD,NDSET,NWS(10),D50,SIGMAP
C
C OUTPUT FROM CHARGING ROUTINE
C
      WRITE(NPRNT,9992)
 9992 FORMAT(1H1)
      WRITE(NPRNT,356)
  356 FORMAT(/T3,'CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHAR
     1GN OR CHGSUM'/)
      IF((NCALC.EQ.1).OR.(NEST.EQ.2)) GO TO 1880
      WRITE(NPRNT,1879)
 1879 FORMAT(/T3,'SRI THEORY USED FOR PARTICLE CHARGING')
      GO TO 1881
 1880 CONTINUE
      WRITE(NPRNT,1882)
 1882 FORMAT(/T3,'SUM OF CLASSICAL FIELD AND DIFFUSIONAL CHARGES USED FO
     1R PARTICLE CHARGING')
 1881 CONTINUE
      WRITE(NPRNT,2500)
 2500 FORMAT(//T2,'INCREMENT NO.',T20,'Q/QSATF FOR INDICATED PARTICLE SI
     1ZES')
      JS=1
      KS=8
 6544 CONTINUE
      IF(KS-NS) 6541,6542,6542
 6542 CONTINUE
      KS=NS
 6541 CONTINUE
      WRITE(NPRNT,357) (DIAM(J),J=JS.KS)
 357  FORMAT(//T4,10(E11.4,2X)//)
      DO 360 I=1,NF
      DO 359 J=JS,KS
      IF(NVI.EQ.1) GO TO 4692
      N = NI/2
      QSATM=(4.*PI*EPSO*(RAD(J)+TMFP)**2)*EAVG(N)*(1.+2.*((EPS-1.)/
     1(EPS+2.))*(RAD(J)/(RAD(J)+TMFP))**3)*VRATIO
      YY(J)=XDC(I,J)/QSATM
      GO TO 359
 4692 CONTINUE
      YY(J)=XDC(I,J)/QSAT(J)
  359 CONTINUE
      WRITE(NPRNT,358) I,(YY(J),J=JS.KS)
  358 FORMAT(T3,I2,T6,10(F7.4,6X))
  368 CONTINUE
      IF(K8.EQ.N8) GO TO 6543
      J8=J8+8
      K8=K8+8
      GO TO 6544
 6543 CONTINUE
      WRITE(NPRNT,9992)
      WRITE(NPRNT,432)
  432 FORMAT(/T5,'CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT
     1'//T3,'INCREMENT',T20,'CHARGE FOR INDICATED PARTICLE SIZES')
      J8=1
      K8=8
 6565 CONTINUE
      IF(K8-N8) 6566,6567,6567
 6567 CONTINUE
      K8=N8
 6566 CONTINUE
      WRITE(NPRNT,425) (DIAM(J),J=J8.K8)
  425 FORMAT(//T8,10(E11.4,3X)//)
      DO 431 I=1.NF
      WRITE(NPRNT,430) I,(XDC(I,J),J=J8,K8)
  430 FORMAT(T3,I2,T6,10(E13.5,1X))
  431 CONTINUE
      IF(K8.EQ.N8) GO TO 6568
      J8=J8+8
      K8=K8+8
      GO TO 6565
 6568 CONTINUE
      RETURN
      END
      SUBROUTINE ADJUST
C                             *************************************************
C                             *                                               *
C                             *  RAPPING REENTRAINMENT PROCEDURE IN           *
C                             *                                               *
C                             *  THIS SUBROUTINE WAS DEVELOPED UNDER          *
C                             *                                               *
C                             *  THE SPONSORSHIP OF E.P.R.I. BY SO.R.I.       *
C                             *                                               *
C                             *************************************************
      DOUBLE PRECISION EFESR,DLOG,EFFWR
      REAL LINCS
      DIMENSION RPCNT(20),DMDLD(20),WUNCOR(20),RDMDLD(20),CDMDLD(20),
     1PCTOT(20),CPCTOT(20),WSL(20),PXS(20),PRCUNR(21),RPRCU(21),
     2PRCUC(21),EUNCOR(20)
      COMMON/BLK1/DIAM(20),ONO(20),DXS(20),XMV(20),PCNT(20),RAD(20),
     1CCF(20),PRCU(21)
      COMMON/BLK2/LSECT(10),LINCS(10),PS(10)
      COMMON/BLK3/VG,ATOTAL,DD,ETAO,DL,PL,RHO
      COMMON/BLK4/NS
      COMMON/BLK5/ZMMDI,SIGMI,NONID,NRAPD,TDK,NUMSEC,NEFF,NTEMP,GFIT
      COMMON/BLK6/VOL(20),XNO(20),Q(20),WS(20),ITL(40),DW(45),AS(10),
     1VOS(10),TCS(10),WLS(10),ACS(10),BS(10),SYS(10),VGS(10),VGASS(10),
     2TEMPS(10),VISS(10),QSAT(20),U,E,EPSO,PI,ERAVG,BC,TEMP,EPS,VAVC,
     3OLDQ(20),OLDXNO(20),RFS(10),START1(10),START2(10),START3(10),
     4VSTAR(10)
      COMMON/BLK11/ENDPT(21),NENDPT
      COMMON/BLK12/ARD50(10),ARSIGM(10),ASNUCK(15),AZNUMS(15),AZIGGY(15)
      COMMON/BLK17/NREAD,NPRNT
      COMMON/BLK18/SCOREF,CZMDL,CSIGMO,NRUN,SNUCK,ZIGGY,RMMD,RSIGMA
      COMMON/BLK19/LK,DV,NN,NUMINC,NX,NY,NDATA,NEST,NDIST,NITER,IFINAL,
     1JI1,JI2,VISKIP,VISAME,US,FPATH,EBD,NDSET,NWS(10),D50,SIGMAP
      NRUN = 0
      NS1=NS+1
      NUMS1=NUMSEC-1
      CONVF=3.67E+03*(TDK/PS(NUMSEC))
      NRAPDC=0
      X=0.0
      DO 1555 I=1,NS
      EFESR=DXS(I)/ONO(I)
      IF(EFESR.GT.0.999999) EFESR=0.999999
      X=X+EFESR*PCNT(I)
 1555 CONTINUE
 1713 CONTINUE
      NRAPDC=NRAPDC+1
      IF(NRAPDC.EQ.1) GO TO 6078
      GO TO 6080
 6078 CONTINUE
      ARD50(1)=6.0
      ARSIGM(1)=2.5
      RMMD=6.0
      RSIGMA=2.5
      GO TO 6079
 6080 CONTINUE
      RMMD=ARD50(NRAPDC)
      RSIGMA=ARSIGM(NRAPDC)
 6079 CONTINUE
      CALL LNDIST(RMMD,RSIGMA,RPRCU,RPCNT)
      DO 7575 I=1,NS
      RPCNT(I)=RPCNT(I)*1.E+02
 7575 CONTINUE
      NONCK=0
 1867 CONTINUE
      NONCK=NONCK+1
      SNUCK=ASNUCK(NONCK)
      ZIGGY=AZIGGY(NONCK)
      ZNUMS=AZNUMS(NONCK)
      WRITE(NPRNT,18)
   18 FORMAT(1H1,' PARTICLE SIZE RANGE STATISTICS'/)
      WRITE(NPRNT,1868) NONCK
 1868 FORMAT(/' CORRECTIONS FOR NONIDEALITIES USING SET NO. ',I2,' OF CO
     1RRECTION PARAMETERS'/)
C
C        PRINT DIAM., PERCENT, AND EFFICIENCY FOR EACH SIZE RANGE
C
      WRITE(NPRNT,19)
   19 FORMAT(4X,'SIZE',5X,'CCF',2X,'INLET %',1X,'OUTLET %',1X,'COR. OUTL
     1ET %',1X,'NO-RAP EFF.',1X,'NO-RAP W',2X,'NO-RAP P',2X,'COR. EFF.',
     23X,'COR. W',5X,'COR. P')
C
C
      Y=0.0
      DO 2990 I=1,NS
      EFESR=DXS(I)/ONO(I)
      IF (EFESR .GT. .999999 ) EFESR = .999999
      XEP=EFESR*100.D0
      IF (XEP .GE. 99.9999  ) XEP = 99.9999
      IF(EFESR.GE.0.99999)WY=XMV(I)*100.
      IF(EFESR.LT.0.99999)WY=(VG/ATOTAL)*100.*ALOG(100./(100.-XEP))
      IF(ZIGGY-0.0)4704,4704,4705
 4704 F1=1.
      GO TO 4706
 4705 CONTINUE
      F1=1.+.766*EFESR*ZIGGY**1.786+.0755*ZIGGY*DLOG(1.D0/(1.D0-EFESR))
 4706 CONTINUE
      IF(SNUCK-0.0)4701,4701,4702
 4701 F2=1.
      GO TO 4703
 4702 F2=DLOG(1.-EFESR)/(ZNUMS*DLOG(SNUCK+(1.-SNUCK)*(1.0-EFESR)**(1./
     1ZNUMS)))
 4703 CONTINUE
      WYS=WY/F2
      WYV=WY/F1
      ZNLFF = F1*F2
      WYSV=WY/ZNLFF
      WUNCOR(I)=WY
      EUNCOR(I)=EFESR*100.
      CALL WADJST(DIAM,I,WYSV,ONO,PXS,ATOTAL,VG,EFESR)
      IF (EFESR .GT. .999999 ) EFESR = .999999
      XEP=EFESR*100.D0
      IF (XEP .GE. 99.9999  ) XEP = 99.9999
      IF(EFESR.GE.0.99999)WY=XMV(I)*100.
      IF(EFESR.LT.0.99999)WY=(VG/ATOTAL)*100.*ALOG(100./(100.-XEP))
      PXS(I)=EFESR*ONO(I)
      Y = Y + EFESR * PCNT(I)
 2990 CONTINUE
      IDC=0
      SPO=0.
      SCPO=0.
      IX=0
 1341 CONTINUE
      SCOREF = 0.0
      IDC=IDC+1
      DO 3500 I=1,NS
      IX=IX+1
      EFFSR=PXS(I)/ONO(I)
      IF (EFESR .GT..999999 ) EFESR = .999999
      XEP=EFESR*100.D0
      IF (XEP .GE. 99.9999  ) XEP = 99.9999
      IF(EFESR.GE.0.99999)HY=XMV(I)*100.
      IF(EFESR.LT.0.99999)HY=(VG/ATOTAL)*100.*ALOG(100./(100.-XEP))
      XY=PCNT(I)*100.
      PENTR=100.-XEP
      PCTOT(I)=PENTR*PCNT(I)*1.E-02
      IF(IX.GT.1) GO TO 7130
      CLPTLS=0.
      DO 1 IS=1,NUMS1
      CLPTLS=CLPTLS+FLOAT(LSECT(IS))*LINCS(IS)*0.305
    1 CONTINUE
      NYX=0
 1430 CONTINUE
      NYX=NYX+1
      IF(NYX.EQ.2) GO TO 1431
      XEFF=Y
      IF(NEFF.EQ.2) XEFF=X
      EXPONT=ALOG(1./(1.-XEFF))
      XMELS=DL*EXP(-(EXPONT*CLPTLS)/PL)
      XMCLS=XMELS*(1.-EXP(-(EXPONT*FLOAT(LSECT(NUMSEC))*LINCS(NUMSEC)*0.
     1305)/PL))
      XMLLS=XMELS-XMCLS
      XMCLS=XMCLS*CONVF
      IF(NTEMP.EQ.1) RAPLOS=0.155*XMCLS**0.905
      IF(NTEMP.EQ.2) RAPLOS=0.618*XMCLS**0.894
      GO TO 1432
 1431 CONTINUE
      EXPONT=ALOG(1./(1.-Y))
      YMELS=DL*EXP(-(EXPONT*CLPTLS)/PL)
      YMCLS=YMELS*(1.-EXP(-(EXPONT*FLOAT(LSECT(NUMSEC))*LINCS(NUMSEC)*0.
     1305)/PL))
      YMLLS=YMELS-YMCLS
      YMCLS=YMCLS*CONVF
 1432 CONTINUE
      IF(NYX.EQ.1) GO TO 1430
 7130 CONTINUE
      RNS=((RAPLOS/(DD*CONVF))*RPCNT(I)*1.E-02)/((3.14159*DIAM(I)**3)/6.
     1)
      HYSV=HY
      EFFWR=(ONO(I)*(1.-EXP(-(ATOTAL*HYSV)/(100.*VG)))-RNS)/ONO(I)
      CRNP = ONO(I)*(1.-EXP(-(ATOTAL*HYSV)/(100.*VG)))- RNS
      IF(CRNP.LE.0.0) EFFWR = EFESR
      IF(EFFWR.GT..999999) EFFWR=.999999
      COREFF=EFFWR*100.D0
      IF(COREFF.GE.99.9999) COREFF=99.9999
      IF(EFFWR.GE.0.99999) HYP=HYSV
      IF(EFFWR.LT.0.99999) HYP=(VG/ATOTAL)*100.*ALOG(100./(100.-COREFF))
      SCOREF = SCOREF + COREFF*PCNT(I)
      CPENTR=100.-COREFF
      CPCTOT(I)=CPENTR*PCNT(I)*1.E-02
      IF(IDC.NE.1) GO TO 1343
      SPO=SPO+PCTOT(I)
      SCPO=SCPO+CPCTOT(I)
 1343 CONTINUE
      SL=(1.0-EFESR)*ONO(I)
      WSL(I)=SL*(1.33333*3.14159*RAD(I)**3)*DD
      IF(IPC.EQ.1) GO TO 1344
      PCTOT(I)=(PCTOT(I)/SPO)*100.
      CPCTOT(I)=(CPCTOT(I)/SCPO)*100.
      DLD=ALOG10(ENDPT(I+1))-ALOG10(ENDPT(I))
      DMDLD(I)=(PCTOT(I)*YMLLS*CONVF*1.E-02)/DLD
      RDMDLD(I)=(RPCNT(I)*RAPLOS*1.E-02)/DLD
      CDMDLD(I)=DMDLD(I)+RDMDLD(I)
      WRITE(NPRNT,2291) DIAM(I),CCF(I),XY,PCTOT(I),CPCTOT(I),XEP,WY,
     1PENTR,COREFF,WYP,CPENTR
 2291 FORMAT(1X,1PE10.3,1X,0PF6.3,1X,F6.3,2X,F7.4,5X,F7.4,4X,F8.4,3X,F7.
     13,2X,F8.4,3X,F8.4,2X,F7.3,4X,F8.4)
 1344 CONTINUE
 3540 CONTINUE
      IF(IDC.EQ.1) GO TO 1341
C
      Y=Y*100.
      X = X * 100.
      WRITE(NPRNT,2292) ETAO,X
 2292 FORMAT('0',4X,'EFFICIENCY - STATED = ',F5.2,5X,'COMPUTED =' ,F8.4
     S,5X,'CONVERGENCE OBTAINED')
      X=X/100.
      WRITE(NPRNT,3675) Y
 3675 FORMAT(//5X,23HADJUSTED NO-RAP EFF. = ,F8.4)
      WRITE(NPRNT,5802) ZMMDI
 5802 FORMAT(5X,'MMD OF INLET SIZE DISTRIBUTION =',1PE11.3)
      WRITE(NPRNT,5803) SIGMI
 5803 FORMAT(5X,'SIGMAP OF INLET SIZE DISTRIBUTION =',1PE11.3)
      IF(NDIST.EQ.1) WRITE(NPRNT,9250) GFIT
 9250 FORMAT(5X,'LOG-NORMAL GOODNESS OF FIT = ',F6.3)
C
C CALCULATE MMD OF EFFLUENT UNDER NO-RAP CONDITIONS
C
      PRCUNR(1)=0.
      SUMNR=PRCUNR(1)
      DO 1750 I=1,NS
      SUMNR=SUMNR+PCTOT(I)
      PRCUNR(I+1)=SUMNR
 1750 CONTINUE
      CALL LNFIT(PRCUNR,ZMDL,SIGMO,ZGFIT)
 2982 WRITE(NPRNT,2997) ZMDL
 2997 FORMAT(5X,'MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =',1PE11.3)
      WRITE(NPRNT,5801) SIGMO
 5801 FORMAT(5X,'SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =',1PE11.3)
      WRITE(NPRNT,9250) ZGFIT
      COREFW=(VG/ATOTAL)*100.*ALOG(100./(100.-SCOREF))
      WZ=(VG/ATOTAL)*100.*ALOG(100./(100.-Y))
      WRITE(NPRNT,2998) WZ
 2998 FORMAT(5X,'PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS ='
     1,F7.3//)
      PRCUC(1)=0.
      SUMC=PRCUC(1)
      DO 1751 I=1,NS
      SUMC=SUMC+CPCTOT(I)
      PRCUC(I+1)=SUMC
 1751 CONTINUE
      CALL LNFIT(PRCUC,CZMDL,CSIGMO,CGFIT)
      WRITE(NPRNT,4615) ZIGGY,SNUCK,ZNUMS
4615   FORMAT(5X,'SIGMAG=',2X,F7.3,2X,'WITH',F7.3,' SNEAKAGE OVER',2X,
     1F7.3,2X,'STAGES')
      WRITE(NPRNT,7900) NTEMP
7900  FORMAT(5X,'NTEMP =',I2)
      WRITE(NPRNT,7901) RMMD
7901  FORMAT(5X,'RMMD =',F6.2)
      WRITE(NPRNT,7902) RSIGMA
7902  FORMAT(5X,'RSIGMA =',F5.2)
      WRITE(NPRNT,5002) SCOREF
5002   FORMAT(5X,'CORR. EFF. = ',F8.4)
      WRITE(NPRNT,8352) CZMDL
8352  FORMAT(5X,'CORRECTED MMD OF EFFLUENT =',1PE11.3)
      WRITE(NPRNT,5800) CSIGMD
5800  FORMAT(5X,'CORRECTED SIGMAP OF EFFLUENT =',1PE11.3)
      WRITE(NPRNT,9250) CGFIT
      WRITE(NPRNT,5003) COREFW
5003  FORMAT(5X,'CORRECTED PRECIPITATION RATE PARAMETER =',F8.2)
      WRITE(NPRNT,6565)
6565  FORMAT(1H1,' UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND
     1 DISCRETE OUTLET MASS LOADINGS'//)
      WRITE(NPRNT,1980)
1980  FORMAT(1X,16HIDEAL UNADJUSTED,3X,16HIDEAL UNADJUSTED,7X,6HNO-RAP,1
     10X,12HRAPPING PUFF,6X,15HNO-RAP+RAP PUFF,5X,12HRAPPING PUFF,4X,8HP
     2ARTICLE)
      WRITE(NPRNT,1981)
1981  FORMAT(1X,17HMIG. VEL.(CM/SEC),4X,13HEFFICIENCY(%),4X,17HDM/DLOGD(
     1MG/DSCM),2X,17HDM/DLOGD(MG/DSCM),2X,17HDM/DLOGD(MG/DSCM),2X,15HDIS
     2TRIBUTION(%),2X,8HDIAM.(M))
      DO 1982 M=1,NS
      WRITE(NPRNT,1983) WUNCOR(M),FUNCOR(M),DMDLD(M),RDMDLD(M),
     1CDMDLD(M),RPCNT(M),DIAM(M)
1983  FORMAT(1X,1PE10.3,4(10X,1PE10.3),7X,1PE10.3,6X,1PE10.3)
1982  CONTINUE
      NRUN = NRUN + 1
      CALL PRTSUM
      IF(NONCK.LT.NONID) GO TO 1867
      IF(NRAPDC.LT.NRAPD) GO TO 1713
      RETURN
      END
      SUBROUTINE WADJST (DIAM,I,WY,ONO,PXS,ATOTAL,VG,EFESR)
C                                            *********************************************
C                                            *                                           *
C                                            *  CORRECTION FACTORS IN THIS SUBROUTINE    *
C                                            *                                           *
C                                            *  ARE BASED ON DATA TAKEN UNDER            *
C                                            *                                           *
C                                            *  E.P.R.I. SPONSORSHIP BY SO.R.I.          *
C                                            *                                           *
C                                            *********************************************
      DOUBLE PRECISION EFESR
      DIMENSION DIAM(20),ONO(20),PXS(20),CFACT(24),DCHECK(24)
      DATA CFACT/2.43,2.325,2.24,2.17,2.11,2.05,2.00,1.965,1.92,1.885,1.
     185,1.82,1.79,1.76,1.74,1.71,1.685,1.5,1.37,1.27,1.18,1.115,1.05,1.
     200/
      DATA DCHECK/.2E-06,.25E-06,.3E-06,.35E-06,.4E-06,.45E-06,.5E-06,.5
     15E-06,.6E-06,.65E-06,.7E-06,.75E-06,.8E-06,.85E-06,.9E-06,.95E-06,
     21.E-06,1.5E-06,2.E-06,2.5E-06,3.E-06,3.5E-06,4.E-06,4.5E-06/
      IF((DIAM(I).LT.2.0E-07).OR.(DIAM(I).GE.4.5E-06)) GO TO 6
      DO 3 L=1,23
      IF((DIAM(I).GE.DCHECK(L)).AND.(DIAM(I).LE.DCHECK(L+1))) GO TO 4
      GO TO 3
    4 CONTINUE
      WFACT=CFACT(L)-((DIAM(I)-DCHECK(L))/(DCHECK(L+1)-DCHECK(L)))*
     1(CFACT(L)-CFACT(L+1))
      WY=WY*WFACT
      EFESR=1.-EXP(-(ATOTAL*WY)/(100.*VG))
      PXS(I)=EFESR*ONO(I)
      GO TO 5
    3 CONTINUE
    6 CONTINUE
      EFESR=1.-EXP(-(ATOTAL*WY)/(100.*VG))
      PXS(I)=EFESR*ONO(I)
    5 CONTINUE
      RETURN
      END
      SUBROUTINE LNDIST (D50,SIGMAP,PRCU,PCNT)
      DIMENSION Y(100),Z(100),AREA(20),PRCU(21),PCNT(20)
      COMMON/BLK4/NS
      COMMON/BLK11/ENDPT(21),NENDPT
      PI=3.1416
      SIGMAZ=ALOG(SIGMAP)
      N=NS+2
      NINC=100
      ASUM=0.
      K=0
      DO 240 J=1,N
      IF(J.EQ.1)GO TO 230
      IF(J.EQ.(N))GO TO 232
      X2=ALOG(ENDPT(J))
      X1=ALOG(ENDPT(J-1))
      GO TO 233
230   CONTINUE
      X1=ALOG(0.01)
      X2=ALOG(ENDPT(J))
      GO TO 233
232   CONTINUE
      X1=ALOG(ENDPT(J-1))
      X2=ALOG(1000.)
233   CONTINUE
      DX=(X2-X1)/99.
      D=X1
      SGT1=1./(SIGMAZ*(2.*PI)**.5)
      SGT2=2.*SIGMAZ**2
      DO 234 I=1,NINC
      Y(I)=SGT1*EXP(-(D-ALOG(D50))**2/SGT2)
      D=D+DX
234   CONTINUE
      CALL QTFE(DX,Y,Z,NINC)
      ASUM=ASUM+Z(NINC)
      IF(J.LT.N) PRCU(J)=ASUM
      IF((J.EQ.1).OR.(J.EQ.N))GO TO 240
      K=K+1
      AREA(K)=Z(NINC)
240   CONTINUE
      DO 241 I=1,NS
      PCNT(I)=AREA(I)/ASUM
241   CONTINUE
      SUM=0.
      DO 2 I=1,NS
      SUM=SUM+PCNT(I)
2     CONTINUE
      CHECK1 = 1.0 - SUM
      PCNT(NS)=PCNT(NS)+CHECK1
      CHECK2 = 1.0 - PRCU(NENDPT)
      PRCU(NENDPT)=PRCU(NENDPT)+CHECK2
      RETURN
      END
      SUBROUTINE QTFE (DX,Y,Z,NINC)
      DIMENSION Y(1),Z(1)
      SUM2=0.
      IF(NINC - 1) 4,3,1
    1 DDX=.5*DX
C
C     INTEGRATION LOOP
      DO2 I=2,NINC
      SUM1=SUM2
      SUM2=SUM2+DDX*(Y(I)+Y(I-1))
    2 Z(I-1)=SUM1
    3 Z(NINC)=SUM2
    4 RETURN
      END
      SUBROUTINE LNFIT (PRCU,D50,SIGMAP,GFIT)
C     THIS SUBROUTINE FITS CUMPERCENT CURVE TO A LOGNORMAL DISTRIBUTION
      DIMENSION Z(21),Y(21),PRCU(21)
      COMMON/BLK11/ENDPT(21),NENDPT
      NSTAG=0
      J=0
      DO 1 I=1,NENDPT
      IF(PRCU(I).LE.0.0)GO TO 1
      J=J+1
      Z(J)=ALOG(ENDPT(I))
      IF(PRCU(I).GE.99.0) GO TO 4
      IF(PRCU(I).GT.50.)GO TO 3
      XY=PRCU(I)/100.
2     XYY=SQRT(ALOG(1.0/XY**2))
      Y(J)=XYY-((2.515517+0.802853*XYY+0.010328*XYY**2)/(1.0+1.432788*X
     1YY+0.189269*XYY**2+0.001308*XYY**3))
      IF(PRCU(I).GT.50.)GO TO 5
      Y(J)=-Y(J)
      GO TO 5
3     XY=1.0-(PRCU(I)/100.)
      GO TO 2
5     NSTAG=NSTAG+1
1     CONTINUE
C     CALL CURVE FIT ROUTINE
4     CALL CFIT(A,B,GFIT,NSTAG,Z,Y)
C     CALCULATE D50 AND SIGMAP
      D50=EXP(-A/B)
      SIGMAP=EXP(1.0/B)
      RETURN
      END
      SUBROUTINE CFIT (A,B,R,NSTAG,Z,Y)
C     THIS SUBROUTINE FITS A STRAIGHT LINE, Y=A+BX, USING LEAST SQUARES
      DIMENSION Z(21),Y(21)
      XN=0.0
      SUMX=0.0
      SUMY=0.0
      SUMXY=0.0
      SUMXX=0.0
      SUMYY=0.0
      DO 6 I=1,NSTAG
      SUMX=SUMX+Z(I)
      SUMY=SUMY+Y(I)
      SUMXY=SUMXY+Z(I)*Y(I)
      SUMXX=SUMXX+Z(I)**2
      SUMYY=SUMYY+Y(I)**2
      XN=XN+1.0
    6 CONTINUE
C     CALCULATE A,B
      B=(XN*SUMXY-SUMX*SUMY)/(XN*SUMXX-SUMX**2)
      A=(SUMXX*SUMY-SUMX*SUMXY)/(XN*SUMXX-SUMX**2)
      R=SQRT(B*((XN*SUMXY-SUMX*SUMY)/(XN*SUMYY-SUMY**2)))
      RETURN
      END
      SUBROUTINE PRTSUM
      REAL LINCS
      COMMON/BLK2/LSECT(10),LINCS(10),PS(10)
      COMMON/BLK3/VG,ATOTAL,DD,ETAO,DL,PL,RHO
      COMMON/BLK5/ZMMDI,SIGMI,NONID,WRAPD,TOK,NUMSEC,NEFF,NTEMP,GFIT
      COMMON/BLK6/VOL(20),XNO(20),Q(20),WS(20),ITL(40),DW(45),AS(10),
     1VOS(10),TCS(10),WLS(10),ACS(10),BS(10),SVS(10),VGS(10),VGASS(10),
     2TEMPS(10),VISS(10),QSAT(20),U,E,EPSO,PI,ERAVG,BC,TEMP,EPS,VAVC,
     3OLDQ(20),OLDXNO(20),RFS(10),START1(10),START2(10),START3(10),
     4VSTAR(10)
      COMMON/BLK17/NREAD,NPRNT
      COMMON/BLK18/SCOREF,CZMDL,CSIGMO,NRUN,SNUCK,ZIGGY,RMMD,RSIGMA
      SCA=ATOTAL/VG
      VOSUM=0,
      CDSUM=0.
      DO 6571 I=1,NUMSEC
      VOSUM=VOS(I)*FLOAT(LSECT(I))*LINCS(I)*0.305+VOSUM
      CDSUM=(TCS(I)/(AS(I)*9.3E-02))*1.E+05*FLOAT(LSECT(I))*LINCS(I)*
     10.305+CDSUM
 6571 CONTINUE
      AVO=VOSUM/PL
      ACD=CDSUM/PL
      RHOCGS=RHO*100.
      WRITE(NPRNT,1994)
 1994 FORMAT(1H1)
      WRITE(NPRNT,9520)
 9520 FORMAT(9X,'*******************************************************
     1***************************************************************')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,1060)
 1060 FORMAT(9X,'*',118X,'*')
      WRITE(NPRNT,9500)
 9500 FORMAT(9X,'*',39X,'SUMMARY TABLE OF ESP OPERATING',45X,'*')
      WRITE(NPRNT,9501)
 9501 FORMAT(9X,'*',41X,'PARAMETERS AND PERFORMANCE',47X,'*')
      WRITE(NPPNT,1060)
      WRITE(NPRNT,1060)
      WRITE(NPRNT,1060)
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9502) NRUN
 9502 FORMAT(9X,'*',46X,'DATA SET NUMBER ',I3,49X,'*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9503) SCOREF,SCA
 9503 FORMAT(9X,'*',12X,'ESP PERFORMANCE:',5X,'EFFICIENCY = ',F8.4,' %',
     15X,'SCA = ',1PE10.3,' M**2/(M**3/SEC)',21X,'*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9504) AVO
 9504 FORMAT(9X,'*',12X,'ELECTRICAL CONDITIONS:',5X,'AVG. APPLIED VOLTAG
     1E = ',1PE10.3,' V',40X,'*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9505) ACD
 9505 FORMAT(9X,'*',39X,'AVG. CURRENT DENSITY = ',F7.2,' NA/CM**2',36X,'
     1*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9506) RHOCGS
 9506 FORMAT(9X,'*',39X,'RESISTIVITY = ',1PE10.3,' OHM-CM',44X,'*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9507) ZMMDI,SIGMI
 9507 FORMAT(9X,'*',12X,'SIZE DISTRIRUTIONS:',5X,'INLET MMD = ',1PE10.3,
     1' UM',5X,'INLET SIGMAP = ',1PE10.3,23X,'*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9508) CZMDL,CSIGMO
 9508 FORMAT(9X,'*',36X,'OUTLET MMD = ',1PE10.3,' UM',5X,'OUTLET SIGMAP
     1= ',1PE10.3,21X,'*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9509) SNUCK,ZIGGY
 9509 FORMAT(9X,'*',12X,'NONIDEAL PARAMETERS:',5X,'GAS SNEAKAGE FRACTION
     1 = ',F4.2,' /SECTION',5X,'GAS VELOCITY SIGMAG = ',F4.2,9X,'*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9510) RMMD,RSIGMA
 9510 FORMAT(9X,'*',37X,'RAPPING MMD = ',1PE10.3,' UM',5X,'RAPPING SIGMA
     1P = ',1PE10.3,18X,'*')
      WRITE(NPRNT,1060)
      WRITE(NPRNT,1060)
      WRITE(NPRNT,9520)
      RETURN
      END
      BLOCK DATA
      LOGICAL LTEST
      COMMON /BLK22/ LTEST,RHO(15,15),V(15,15),EX(15,15),EY(15,15)
      DATA LTEST/.FALSE./,RHO/225*0./,V/225*0./,EX/225*0./,EY/225*0./
      END
      SUBROUTINE CMAN (VW,NX,NY,SX,SY,PI,AC,NWIRE)
C   COOPERMAN SERIES DETERMINATION FOR VOLTAGE WIRE TO PLATE
C   FOR SUBROUTINE EFIELD
      REAL NUM,M,NWIRE
      LOGICAL LTEST
      COMMON /BLK13/VCOOP(15,15),NVII
      COMMON/BLK21/ECX(15,15),ECY(15,15),X1(15),Y1(15),AX(15),AY(15)
      COMMON /BLK22/ LTEST,RHO(15,15),V(15,15),EX(15,15),EY(15,15)
      NX1=NX-1
      NY1=NY-1
      DO 402 I=1,NX
      IF(NVII-1)301,300,301
  300 I=NX
  301 CONTINUE
      DO 430 J=1,NY
      X=FLOAT(I-1)*SX/FLOAT(NX1)
      IF(LTEST)X=X1(I)
      Y=FLOAT(J-1)*SY/FLOAT(NY1)
      IF(LTEST)Y=Y1(J)
      IF(X.EQ.0..AND.Y.EQ.0.)GO TO 440
      GO TO 450
 440  VCOOP(I,J)=VW
      GO TO 430
 450  CONTINUE
      M=-NWIRE
      NUM=0.0
      DENOM=0.0
      EX0=0.
      EY0=0.
      EXSUM=0.
      EYSUM=0.
  490 E1=PI*(Y-(2.*M*SY))/(2.*SX)
      F1=PI*X/(2.*SX)
      G1=PI*M*SY/SX
      H1=PI*AC/(2.*SX)
      E2=(EXP(E1)+EXP(-E1))/2.
      F2=COS(F1)
      G2=(EXP(G1)+EXP(-G1))/2.
      H2=COS(H1)
      TT=(E2-F2)/(E2+F2)
      TB=(G2-H2)/(G2+H2)
      F=ALOG(TT)
      G=ALOG(TB)
      NUM=NUM+F
      DENOM=DENOM+G
      H3=SIN(H1)
      F3=SIN(F1)
      E3=(EXP(E1)-EXP(-E1))/2.
      G3=(EXP(G1)-EXP(-G1))/2.
      SUMX=F3/(E2-F2)+F3/(E2+F2)
      SUMY=E3/(E2-F2)-E3/(E2+F2)
      S1=H3/(G2-H2)+H3/(G2+H2)
      S2=G3/(G2-H2)-G3/(G2+H2)
      EXSUM=EXSUM+SUMX
      EYSUM=EYSUM+SUMY
      EX0=EX0+S1
      EY0=EY0+S2
      IF(M.LT.NWIRE) GO TO 408
      GO TO 410
 408  M=M+1.0
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      GO TO 490
  410 VCOOP(I,J)=VW*NUM/DENOM
      ECX(I,J)=-(PI*VW/2,/SX/DENOM)*FXSUM
      ECY(I,J)=-(PI*VW/2./SX/DENOM)*FYSUM
  430 CONTINUE
  402 CONTINUE
   404 CONTINUE
      ECX(1,1)=-(PI*VW/2,/SX/DENOM)*FX0
      ECY(1,1)=-(PI*VW/2./SX/DENOM)*FY0
      RETURN
      END
```

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      SUBROUTINE EFLD3 (UEO,AC,VO,SX,SY,NX,NY,AEPLT,TDK,P,RF,
     1START,DSTART,CSTART,IFINAL,VSTART,VW,ACONTY,NWIRE,NEC,EBD,JI1,JI2)
C  EVALUATION OF FIELDS, SPACE CHARGE DENSITY, POTENTIAL , AND
C  CURRENT DENSITY FOR A WIRE-PLATE PRECIPITATOR
      REAL NWIRE,MAXS,MOBILT(15,15)
      LOGICAL LTEST
      DIMENSION RHO(15,15),EX(15,15),OLDRO(15,15),OLDV(15,15),
     1CDNSTY(15,15),V(15,15),EY(15,15),EAVGS(30),CHFIDS(30),ECOLLS(30)
      COMMON/BLK8/EAVG(30),CHFID(30)
      COMMON/BLK9/ECOLL(30)
      COMMON /BLK13/VCOOP(15,15),NVII
      COMMON/BLK17/NREAD,NPRNT
      COMMON/BLK21/ECX(15,15),ECY(15,15),X1(15),Y1(15),AX(15),AY(15)
      COMMON /BLK22/ LTEST,RHO,V,EX,EY
      DATA OLDRO/225*0./,OLDV/225*0./,CDNSTY/225*0./,MOBILT/225*0./
      COSH(Z)=(EXP(Z)+EXP(-Z))/2.
      SINH(Z)=(EXP(Z)-EXP(-Z))/2.
      VO=-1.*VO
      VW=-1.*VSTART
      RO=AC
      RELD=(293./TDK)*(P/1.)
      ROC=100.*RO
      EORO=ROC*RF*(30.*RELD+9.*SQRT(RELD/ROC))*1.E+03
      DO 550 I=1,NX
      DO 550 J=1,NY
      MOBILT(I,J)=UEO
  550 CONTINUE
      PI=3.1416
      EPSO=8.854E-12
      SSTART=START
      MAXS=0.
      NX1=NX-1
      NY1=NY-1
      R=0.975
      IVCK=0
      RC=AC
      DO 1001 II=1,IFINAL
      IF(II.EQ.JI1) START=DSTART
      IF(II.GE.JI2) START=CSTART
      MAXS=MAXS+START
 1526 CONTINUE
      IF((.NOT.LTEST).AND.(NVII.EQ.2))ACONTY=MAXS
      A1=PI/2./SX
      B1=2.*ACONTY/EPSO/MOBILT(NX1,1)
      B1R=SQRT(ABS(B1))
      C1=B1*SY/PI
      P1=R*SX
      VWIR=0.
      EXWIR=0.
      EYWIR=0.
      E1=0.
      E2=0.
      E3=0.
      F1=0.
      F2=0.
      NW=NWIRE
      SUM1=0.
      SIG1=0.
      DO 3601 I=1,NW
      RM=I
      CH=COSH(RM*PI*SY/SX)
      SIG1=SIG1+CH/(CH*CH-COS(A1*AC)*COS(A1*AC))
      SUM1=SUM1+ALOG(ABS((CH-COS(A1*AC))/(CH+COS(A1*AC))))
 3601 CONTINUE
      SUMW=2.*SUM1
      POT1=1./(1./SIN(A1*AC)/SIN(A1*AC)+2.*SIG1)
      SUM1=2.*SUM1+ALOG(ABS((1.-COS(A1*AC))/(1.+COS(A1*AC))))
      IF(R1.GT.SX)R1=SX
      SQON=R1*R1+4.*SX*(SX-R1)
      SQOP=R1*R1+4.*SX*(SX+R1)
      RNN=R1*(2.*SX-R1)
      RNP=R1*(2.*SX+R1)
      ARGR=PI*R1/SX/2.
      FAC1=1.
      IF(R1.LE.SY) GO TO 60
      CALL ARCCOS(SY,R1,ACOS)
      DUM=-ACOS+SY*SQRT(ABS(R1*R1-SY*SY))/R1/R1
      FAC1=(1.+2.*DUM/PI)
      ICOUNT=0
   60 CONTINUE
      EO=EORO/AC
      RLAM=SX*EO*POT1*SUM1/PI/SIN(A1*AC)
      RAD=SQRT(ABS(1.-C1/EO/EO))
      RASX=SQRT(ABS(1.+C1*(SX*SX-AC*AC)/EORO/EORO))
      RAR1=SQRT(ABS(1.+C1*(R1*R1-AC*AC)/EORO/EORO))
      RONSP=R1/(2.*R1*SY/PI/EORO/RAR1+(RAR1-1.)*EORO*(1./SQON+1./SQOP))
     1/(2.*R1*SY/PI/EORO/RAR1+(RAR1-1.)*EORO*(1./SQON+1./SQOP))
      CLAM=EORO*SX*SIN(PI*R1/2./SX)*(2.+R1*(2.*SX-R1)/(R1*R1
     1+4.*SX*(SX-R1))-R1*(2.*SX+R1)/(R1*R1+4.*SX*(SX+R1)))/PI/R1/2.
     2  *(RAR1-1.)
      WLAM=CLAM*FAC1
      VNAUT=CLAM*ALOG(ABS((1.-COS(A1*R1))/(1.+COS(A1*R1))))
     1 -2.*R1R*(SX-R1)*SQRT(ABS(SX-R1))/3.
      VT=VNAUT-EORO*(RAR1-1.   +(RAD-1.)*ALOG(R1/AC)+RAD*ALOG((RAD+1.)/
     1 (RAD+RAR1))+.25*(RAR1-1.)*(ALOG(ABS((AC*AC+4.*SX*(SX-AC))/SQON))
     2 +ALOG(ABS((AC*AC+4.*SX*(SX+AC))/SQOP))))+RLAM*WLAM*SUMW
      IF(NVIT.EQ.1)GO TO 10
      GO TO 30
   10 CONTINUE
      F=VT-VO
      IF(F.EQ.0.)GO TO 30
      IF(ABS(F).LT.1.0E-04*ABS(VO)) GO TO 30
      E3=EORO+0.10*EORO*F/ABS(F)
      IF(F.LT.0.)F1=F
      IF(F.LT.0.)E1=EORO
      IF(F.GT.0.)F2=F
      IF(F.GT.0.)E2=EORO
      IF(F1*F2.LT.0.)E3=(E1*F2-E2*F1)/(F2-F1)
      EORO=E3
      ICOUNT=ICOUNT+1
      IF(ICOUNT.EQ.100)WRITE(NPRNT,  31)
   31 FORMAT(10X,'THE APPLIED POTENTIAL COULD NOT BE MATCHED IN
     1 '100 ITERATIONS'/)
      IF(ICOUNT.GT.100)GO TO 30
      GO TO 60
   30 CONTINUE
      V(1,1)=VT
      CALL CHAN(RLAM,NX,NY,SX,SY,PI,AC,NWIRE)
      X=0.
      DO 3100 I1=1,NX
      IF(NVII.EQ.1)I11=NX
      Y=0.
      DO 3860 I12=1,NY
      IF(LTEST)X=X1(I11)
      IF(LTEST)Y=Y1(I12)
      IF(NVII.EQ.1)X=SX
      X1(I11)=X
      Y1(I12)=Y
      R1=2.*ACDNTY/EPSO/MOBILT(I11,I12)
      R1R=SQRT(ABS(R1))
      C1=R1*SY/PI
      IF((I11.EQ.1).AND.(I12.EQ.1))X=AC
      SQRN=SQON+Y*Y
      SQRP=SQOP+Y*Y
      SQXN=X*X+Y*Y+4.*SX*(SX-X)
      SQXP=X*X+Y*Y+4.*SX*(SX+X)
      ARGX=PI*X/SX/2.
      ARGY=PI*Y/SX/2.
      RAXY=SQRT(ABS(1.+C1*(X*X+Y*Y-AC*AC)/EORO/EORO))
      RASXY=SQRT(ABS(1.+C1*(SX*SX+Y*Y-AC*AC)/EORO/EORO))
      RAR1Y=SQRT(ABS(1.+C1*(R1*R1+Y*Y-AC*AC)/EORO/EORO))
      COSHY=COSH(A1*Y)
      SINHY=SINH(A1*Y)
      CX=COS(A1*X)
      IF(X.GT.1.00001 *R1) GO TO 3860
      VXYJ=-EORO*(RAR1Y-RAXY+(RAD-1.)*ALOG(SQRT(ABS((R1*R1+Y*Y)/
     1(X*X+Y*Y))))+RAD*ALOG(ABS((RAD+RAXY)/(RAD+RAR1Y)))+(RAR1Y-1.)*
     2 (ALOG(ABS(SQXN/SQRN))+ALOG(ABS(SQXP/SQRP)))/4.)+VNAUT
      EXJ=-EORO*((RAXY-1.)*X/(X*X+Y*Y)-(RAR1 -1.)*((X-2.*SX)/SQXN
     1 +(X+2.*SX)/SQXP)/2.)
      EYJ=-EORO*((RAXY -1.)*Y/(X*X+Y*Y)-(RAR1Y-1.)*Y/(R1*R1+Y*Y)
     1 -(RAR1 -1.)*(Y/SQXN+Y/SQXP-Y/SQRN-Y/SQRP)/2.)
      RHOJ=-EPSO*C1/EORO/RAXY
     1  *1./(1.+((Y+1.E-09)/SY)**9*2.20)/(1.+.162*Y/SY)
     2 -EPSO*EORO*(RAXY-1.)/2.*((SQON-Y*Y)/SQRN/SQRN+(SQOP-Y*Y)/
     3   SQRP/SQRP)*0.9
      GO TO 3861
 3860 CONTINUE
      VXYJ=CLAM*ALOG(ABS((COSHY-CX)/(COSHY+CX)))
     1+2.*R1R*((X-R1)*SQRT(ABS(X-R1))-(SX-R1)*SQRT(ABS(SX-R1)))/3.
      EXJ=-CLAM*PI*SIN(A1*X)*COSHY/SX/(COSHY*COSHY-CX*CX)
     1 -R1R*SQRT(ABS(X-R1))
      EYJ=-CLAM*PI*CX*SINHY/SX/(COSHY*COSHY-CX*CX)
      RHOJ=-EPSO*R1R/2./SQRT(ABS(X-R1+RONSP))
     1  *1./(1.+((Y+1.E-09)/SY)**9*2.33)/(1.+0.75*Y/SY)
 3861 CONTINUE
      SUMV=0.
      SUMEX=0.
      SUMEY=0.
      COSX=COS(PI*X/2./SX)
      SINX=SIN(PI*X/2./SX)
      DO 100 I=1,NH
      RI=I
      COSHN=COSH(PI*(Y-2.*RI*SY)/2./SX)
      COSHP=COSH(PI*(Y+2.*RI*SY)/2./SX)
      SINHN=SINH(PI*(Y-2.*RI*SY)/2./SX)
      SINHP=SINH(PI*(Y+2.*RI*SY)/2./SX)
      DENON=COSHN*COSHN-COSX*COSX
      DENOP=COSHP*COSHP-COSX*COSX
      TERMV=ALOG(ABS((COSHN-COSX)/(COSHN+COSX)))
     1 +ALOG(ABS((COSHP-COSX)/(COSHP+COSX)))
      SUMV=SUMV+TERMV
      TEREX=COSHN/DENON+COSHP/DENOP
      SUMEX=SUMEX+TEREX
      TEREY=SINHN/DENON+SINHP/DENOP
      SUMEY=SUMEY+TEREY
  100 CONTINUE
      VWIR=WLAM*SUMV
      EXWIR=-PI*WLAM*SINX*SUMEX/SX
      EYWIR=-PI*WLAM*COSX*SUMEY/SX
      VXYJ=VXYJ+VWIR
      EXJ=EXJ+EXWIR
      EYJ=EYJ+EYWIR
      V(I11,I12)=VXYJ+VCOOP(I11,I12)
      EX(I11,I12)=EXJ+ECX(I11,I12)
      EY(I11,I12)=EYJ+ECY(I11,I12)
      RHO(I11,I12)=RHOJ
      IF((I11.EQ.1).AND.(I12.EQ.1))X=0.
      Y=Y+SY/FLOAT(NY1)
 3800 CONTINUE
      X=X+SX/FLOAT(NX1)
 3100 CONTINUE
 3150 CONTINUE
      VW=V(1,1)
      EPLT=0.
      DO 1200 J=2,NY
      IF(LTEST)EPLT=EPLT+(EX(NX,J)+EX(NX,J-1))*AY(J-1)/2.
      IF(.NOT.LTEST) EPLT=
     1      EPLT+(EX(NX,J)+EX(NX,J-1))*SY/FLOAT(NX1)/2.
 1200 CONTINUE
      AEPLT=EPLT/SY
      IF(NVIT.EQ.2)WRITE(NPRNT,8888) VW,ACONTY,AEPLT
 8888 FORMAT(38X,'VW = ',1PE11.4,2X,'ACONTY = ',1PE11.4,2X,'AEPLT = ',1P
     1E11.4//)
      IF(ABS(EX(NX,1)).LT.EBD) GO TO 1480
      WRITE(NPRNT,1481) VW,ACONTY
 1481 FORMAT(' THE BREAKDOWN FIELD NEAR THE PLATE IS EXCEEDED AT VW =',E
     111.4,1X,'AND ACONTY =',E11.4)
      GO TO 1525
 1480 CONTINUE
      IF(IVCK.EQ.1) GO TO 1525
      IF(ABS(VW).EQ.ABS(VO)) GO TO 1525
      IF(ABS(VW).GT.ABS(VO)) GO TO 1523
      OLDVW=VW
      OLDCD=ACONTY
      GO TO 1524
 1523 CONTINUE
      MAXS=ACONTY-((ACONTY-OLDCD)/(VW-OLDVW))*(VW-VO)
      VW=OLDVW
      IVCK=1
      GO TO 1526
 1524 CONTINUE
 1001 CONTINUE
 1525 CONTINUE
      IF(NFC.NE.0) GO TO 3000
      K=1
      DO 3001 J=1,NY1
      RSUM=0.
      ESUM=0.
      DO 3002 I=1,NX
```

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```
      IF(J.EQ.1) GO TO 3005
      ESUM=ESUM+(SQRT(EX(I,J)**2+EY(I,J)**2)+SQRT(EX(I,J+1)**2+
     1EY(I,J+1)**2))/(2.*NX)
      GO TO 3006
 3005 CONTINUE
      ESUM=ESUM+SQRT(EX(I,J+1)**2+EY(I,J+1)**2)/(2.*NX)
      IF(I.EQ.NX) ESUM=ESUM-VO/(2.*8X)
 3006 CONTINUE
      RSUM=RSUM-(RHO(I,J)+RHO(I,J+1))/(2.*1.6E-19*NX)
 3002 CONTINUE
      EAVGS(K)=ESUM
      CHFIDS(K)=RSUM
      K=K+1
 3001 CONTINUE
      NYY=NY1
      DO 3003 L=1,NY1
      EAVG(L)=EAVGS(NYY)
      CHFID(L)=CHFIDS(NYY)
      NYY=NYY-1
 3003 CONTINUE
      KK=1
      M1=NY1+1
      M2=2*NY1
      DO 3004 M=M1,M2
      EAVG(M)=EAVGS(KK)
      CHFID(M)=CHFIDS(KK)
      KK=KK+1
 3004 CONTINUE
 3000 CONTINUE
      LL=1
      DO 3007 NN=1,NY1
      ECOLLS(LL)=-(EX(NX,NN)+EX(NX,NN+1))/2.
      LL=LL+1
 3007 CONTINUE
      L1=NY1
      DO 3008 L=1,NY1
      ECOLL(L)=ECOLLS(L1)
      L1=L1-1
 3008 CONTINUE
      L2=1
      I1=NY1+1
      I2=2*NY1
      DO 3009 I=I1,I2
      ECOLL(I)=ECOLLS(L2)
      L2=L2+1
 3009 CONTINUE
      VO=-1.*VO
      START=SSTART
      RETURN
      END
 PROG > 4K
```

APPENDIX G

OUTPUT DATA FOR EXAMPLE 1 (REVISION 2)

```
                    **********************************
                    *                                *
                    *         E.P.A. FSP MODEL       *
                    *                                *
                    *  I.E.R.L.-R.T.P. AND SO.R.T.   *
                    *                                *
                    *     REVISION II, AUG., 1979    *
                    *                                *
                    **********************************

PRINTOUT OF INPUT DATA FOR DATA SET NUMBER  1


DATA ON CARD NUMBER   1

NENDPT = 16   NDATA =  1

DATA ON CARD NUMBER   2

LAB ESP: SCA=125FT2/1000ACFM;J=24.0UA/FT2

DATA ON CARD NUMBER   3

NEST =  1  NDIST =  1  NVI =  3  NX = 10  NY = 10  NITER =  3  NCALC =  0  NRAPD =  1  NEFF =  1  NTEMP =  1  NONID =  2

DATA ON CARD NUMBER   4

NN =  5  NUMINC =  3

DATA ON CARD NUMBER   5

DL =  0.01500 GRN/ACF  PL =  10.0000 FT  ETAO = 99.00000 %  DD =  1000.00 KG/M**3  EPR =  5.100E+00
VRATIO =   1.0300  US = 0.000165 M**2/V-SEC  FPATH =   1.0000  ERD = 1500000. V/M  RHOCGS =  1.00E+09 OHM-CM

DATA ON CARD NUMBER   6

ABNUCK( 1) = 0.00  AZIGGY( 1) = 0.00  AZNUMS( 1) =  4.0
ABNUCK( 2) = 0.10  AZIGGY( 2) = 0.10  AZNUMS( 2) =  4.0


DATA ON CARD NUMBER   7
```

```
ENDPT( 1) =   0.200 UM   ENDPT( 2) =   0.300 UM   ENDPT( 3) =   0.400 UM   ENDPT( 4) =   0.500 UM   ENDPT( 5) =   0.600 UM
ENDPT( 6) =   0.800 UM   ENDPT( 7) =   1.000 UM   ENDPT( 8) =   1.200 UM   ENDPT( 9) =   1.400 UM   ENDPT(10) =   1.800 UM

DATA ON CARD NUMBER   8

ENDPT(11) =   2.200 UM   ENDPT(12) =   3.000 UM   ENDPT(13) =   4.000 UM   ENDPT(14) =   6.000 UM   ENDPT(15) =  10.000 UM
ENDPT(16) =  20.000 UM

DATA ON CARD NUMBER   9

PRCU( 1) =   0.0000 %   PRCU( 2) =   0.0002 %   PRCU( 3) =   0.4002 %   PRCU( 4) =   1.0002 %   PRCU( 5) =   2.6672 %
PRCU( 6) =   7.6672 %   PRCU( 7) =  12.6002 %   PRCU( 8) =  17.6002 %   PRCU( 9) =  21.3332 %   PRCU(10) =  29.3332 %

DATA ON CARD NUMBER  10

PRCU(11) =  36.0002 %   PRCU(12) =  46.6672 %   PRCU(13) =  57.3342 %   PRCU(14) =  68.6672 %   PRCU(15) =  80.6672 %
PRCU(16) = 100.0000 %

DATA ON CARD NUMBER  11

NUMSEC =  3    LSECT( 1) =  3  LSECT( 2) =  3  LSECT( 3) =  6

DATA ON CARD NUMBER  12

AB( 1) =  6.2500E+00 FT**2  VOS( 1) =  4.6000E+04 V  TCS( 1) =  1.5000E-04 A  WLS( 1) =  6.2500E+00 FT
ACS( 1) =  4.6875E-02 IN  BS( 1) =  5.0000E+00 IN  NWS( 1) =  5.0000E+00

DATA ON CARD NUMBER  13

BVS( 1) =  2.5000E+00 IN  VGB( 1) =  2.0000E+02 FT**3/MIN  VGASB( 1) =  3.2000E+00 FT/SEC  TEMPB( 1) =  7.6800E+01 F
PB( 1) =  1.0000E+00 ATM  VISB( 1) =  1.8000E-05 KG/M-SEC  LINCS( 1) =  8.3333E-01 FT

DATA ON CARD NUMBER  14

AB( 2) =  6.2500E+00 FT**2  VOS( 2) =  4.5800E+04 V  TCS( 2) =  1.5000E-04 A  WLS( 2) =  6.2500E+00 FT
ACS( 2) =  4.6875E-02 IN  BS( 2) =  5.0000E+00 IN  NWS( 2) =  5.0000E+00
```

```
DATA ON CARD NUMBER  15

SVS( 2) =  2.5000E+00 IN  VGS( 2) =  2.0000E+02 FT**3/MIN  VGASS( 2) =  3.2000E+00 FT/SEC  TEMPS( 2) =  7.6800E+01 F
PS( 2) =  1.0000E+00 ATM  VISS( 2) =  1.8000E-05 KG/M-SEC  LINCS( 2) =  8.3333E-01 FT

DATA ON CARD NUMBER  16

AS( 3) =  1.2500E+01 FT**2  VOS( 3) =  4.4400E+04 V  TCS( 3) =  3.0000E-04 A  WLS( 3) =  1.2500E+01 FT
ACS( 3) =  4.6875E-02 IN  BS( 3) =  5.0000E+00 IN  NWS( 3) =  1.0000E+01

DATA ON CARD NUMBER  17

SVS( 3) =  2.5000E+00 IN  VGS( 3) =  2.0000E+02 FT**3/MIN  VGASS( 3) =  3.2000E+00 FT/SEC  TEMPS( 3) =  7.6800E+01 F
PS( 3) =  1.0000E+00 ATM  VISS( 3) =  1.8000E-05 KG/M-SEC  LINCS( 3) =  8.3333E-01 FT
```

```
INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


LAB ESP; SCA=125FT2/1000ACFM;J=24.0UA/FT2

CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2         APPLIED VOLTAGE =  4.600E+04 VOLTS       TOTAL CURRENT =  1.500E-04 AMPS
WIRE TO PLATE =  1.270E-01 M            CORONA WIRE RADIUS =  1.191E-03 M        CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  7.869E-05 AMP/M            CURRENT DENSITY =  2.581E-04 AMP/M2      DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M         GAS FLOW RATE =  9.460E-02 M3/SEC        GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                 PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  4.439E+02 M/SEC    PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC         LENGTH INCR. =0.25416565 M               INPUT EFF./INCR. = 31.87

ROVRI     ERAVG        EPLT        AFID        CMCD      MMD         WEIGHT     DUST LAYER   J(PART)      J(ION)    INCR. NO.

1.0860   3.622E+05  2.6176E+05  2.2804E+13    25.8    6.88E-06    1.009E-05   2.957E-04   4.83E-08    2.58E-04       1
1.0505   3.622E+05  2.5984E+05  2.3576E+13    25.8    4.14E-06    6.349E-06   1.860E-04   5.76E-08    2.58E-04       2
1.0292   3.622E+05  2.5867E+05  2.4062E+13    25.8    2.97E-06    4.068E-06   1.192E-04   5.15E-08    2.58E-04       3

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2         APPLIED VOLTAGE =  4.580E+04 VOLTS       TOTAL CURRENT =  1.500E-04 AMPS
WIRE TO PLATE =  1.270E-01 M            CORONA WIRE RADIUS =  1.191E-03 M        CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  7.869E-05 AMP/M            CURRENT DENSITY =  2.581E-04 AMP/M2      DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M         GAS FLOW RATE =  9.460E-02 M3/SEC        GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                 PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  4.439E+02 M/SEC    PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC         LENGTH INCR. =0.25416565 M               INPUT EFF./INCR. = 31.87

ROVRI     ERAVG        EPLT        AFID        CMCD      MMD         WEIGHT     DUST LAYER   J(PART)      J(ION)    INCR. NO.

1.0169   3.606E+05  2.5737E+05  2.4460E+13    25.8    2.41E-06    2.833E-06   8.299E-05   4.50E-08    2.58E-04       4
1.0099   3.606E+05  2.5737E+05  2.4630E+13    25.8    2.10E-06    2.101E-06   6.156E-05   3.93E-08    2.58E-04       5
1.0058   3.606E+05  2.5737E+05  2.4731E+13    25.8    1.86E-06    1.615E-06   4.731E-05   3.43E-08    2.58E-04       6

CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  1.5250 M

COLLECTION AREA =  1.162E+00 M2         APPLIED VOLTAGE =  4.440E+04 VOLTS       TOTAL CURRENT =  3.000E-04 AMPS
WIRE TO PLATE =  1.270E-01 M            CORONA WIRE RADIUS =  1.191E-03 M        CORONA WIRE LENGTH =  3.812E+00 M
CURRENT/M =  7.869E-05 AMP/M            CURRENT DENSITY =  2.581E-04 AMP/M2      DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M         GAS FLOW RATE =  9.460E-02 M3/SEC        GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                 PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  4.439E+02 M/SEC    PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC         LENGTH INCR. =0.25416565 M               INPUT EFF./INCR. = 31.87

ROVRI     ERAVG        EPLT        AFID        CMCD      MMD         WEIGHT     DUST LAYER   J(PART)      J(ION)    INCR. NO.

1.0033   3.496E+05  2.5222E+05  2.5574E+13    25.8    1.66E-06    1.248E-06   3.645E-05   2.92E-08    2.58E-04       7
1.0020   3.496E+05  2.5222E+05  2.5609E+13    25.8    1.54E-06    9.971E-07   2.921E-05   2.55E-08    2.58E-04       8
1.0012   3.496E+05  2.5222E+05  2.5629E+13    25.8    1.45E-06    8.089E-07   2.370E-05   2.23E-08    2.58E-04       9
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1.0007   3.496E+05  2.5222E+05  2.5641E+13   25.8   1.38E-06   6.427E-07   1.941E-05   1.96E-08    2.58E-04     10
1.0004   3.496E+05  2.5222E+05  2.5648E+13   25.8   1.31E-06   5.471E-07   1.603E-05   1.71E-08    2.58E-04     11
1.0002   3.496E+05  2.5222E+05  2.5652E+13   25.8   1.24E-06   4.546E-07   1.332E-05   1.51E-08    2.58E-04     12
EST. EFFICIENCY = 99.00     UNCORRECTED COMPUTED EFFICIENCY = 92.50

INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


LAB ESP; SCA=125FT2/1000ACFM;J=24.0UA/FT2

CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2
WIRE TO PLATE =  1.270E-01 M           APPLIED VOLTAGE =  4.600E+04 VOLTS        TOTAL CURRENT =  1.500E-04 AMPS
CURRENT/M =  7.869E-05 AMP/M           CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  1.906E+00 M
1/2 WIRE TO WIRE =  6.350E-02 M        CURRENT DENSITY =  2.581E-04 AMP/M2       DEPOSIT E FIELD =  2.581E+03 VOLT/M
TEMPERATURE = 297.667 K                GAS FLOW RATE =  9.460E-02 M3/SEC         GAS VELOCITY =  9.760E-01 M/SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC  PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
DUST WEIGHT =  3.250E-06 KG/SEC        MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
                                       LENGTH INCR. =0.25416565 M                INPUT EFF./INCR. = 19.41

ROVRI     ERAVG       EPLT        AFID       CMCD     MMD        WEIGHT     DUST LAYER   J(PART)      J(ION)   INCR. NO.

1.0524   3.622E+05  2.5995E+05  2.3533E+13   25.8   6.89E-06   1.004E-05   2.942E-04   4.80E-08    2.58E-04      1
1.0364   3.622E+05  2.5906E+05  2.3896E+13   25.8   4.15E-06   6.359E-06   1.863E-04   5.77E-08    2.58E-04      2
1.0249   3.622E+05  2.5844E+05  2.4163E+13   25.8   2.97E-06   4.081E-06   1.195E-04   5.16E-08    2.58E-04      3
CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2
WIRE TO PLATE =  1.270E-01 M           APPLIED VOLTAGE =  4.580E+04 VOLTS        TOTAL CURRENT =  1.500E-04 AMPS
CURRENT/M =  7.869E-05 AMP/M           CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  1.906E+00 M
1/2 WIRE TO WIRE =  6.350E-02 M        CURRENT DENSITY =  2.581E-04 AMP/M2       DEPOSIT E FIELD =  2.581E+03 VOLT/M
TEMPERATURE = 297.667 K                GAS FLOW RATE =  9.460E-02 M3/SEC         GAS VELOCITY =  9.760E-01 M/SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC  PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
DUST WEIGHT =  3.250E-06 KG/SEC        MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
                                       LENGTH INCR. =0.25416565 M                INPUT EFF./INCR. = 19.41

ROVRI     ERAVG       EPLT        AFID       CMCD     MMD        WEIGHT     DUST LAYER   J(PART)      J(ION)   INCR. NO.

1.0171   3.606E+05  2.5738E+05  2.4456E+13   25.8   2.41E-06   2.842E-06   8.326E-05   4.51E-08    2.58E-04      4
1.0118   3.606E+05  2.5738E+05  2.4584E+13   25.8   2.10E-06   2.107E-06   6.171E-05   3.94E-08    2.58E-04      5
1.0082   3.606E+05  2.5738E+05  2.4672E+13   25.8   1.86E-06   1.618E-06   4.741E-05   3.44E-08    2.58E-04      6
CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  1.5250 M

COLLECTION AREA =  1.162E+00 M2
WIRE TO PLATE =  1.270E-01 M           APPLIED VOLTAGE =  4.440E+04 VOLTS        TOTAL CURRENT =  3.000E-04 AMPS
CURRENT/M =  7.869E-05 AMP/M           CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  3.812E+00 M
1/2 WIRE TO WIRE =  6.350E-02 M        CURRENT DENSITY =  2.581E-04 AMP/M2       DEPOSIT E FIELD =  2.581E+03 VOLT/M
TEMPERATURE = 297.667 K                GAS FLOW RATE =  9.460E-02 M3/SEC         GAS VELOCITY =  9.760E-01 M/SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC  PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
DUST WEIGHT =  3.250E-06 KG/SEC        MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
                                       LENGTH INCR. =0.25416565 M                INPUT EFF./INCR. = 19.41

ROVRI     ERAVG       EPLT        AFID       CMCD     MMD        WEIGHT     DUST LAYER   J(PART)      J(ION)   INCR. NO.
```

```
1.0055   3.496E+05  2.5235E+05  2.5518E+13    25.8   1.66E-06   1.247E-06   3.653E-05   2.93E-08   2.58E-04    7
1.0039   3.496E+05  2.5235E+05  2.5560E+13    25.8   1.54E-06   9.985E-07   2.925E-05   2.56E-08   2.58E-04    8
1.0027   3.496E+05  2.5235E+05  2.5589E+13    25.8   1.45E-06   8.100F-07   2.373E-05   2.24E-08   2.58E-04    9
1.0019   3.496E+05  2.5235E+05  2.5610E+13    25.8   1.38E-06   6.636F-07   1.944E-05   1.96E-08   2.58E-04   10
1.0013   3.496E+05  2.5235E+05  2.5624E+13    25.8   1.31E-06   5.477E-07   1.605E-05   1.72E-08   2.58E-04   11
1.0009   3.496E+05  2.5235E+05  2.5635E+13    25.8   1.24E-06   4.550E-07   1.333E-05   1.51E-08   2.58E-04   12
```

```
CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHARGN OR CHGSUM

SRI THEORY USED FOR PARTICLE CHARGING

INCREMENT NO.     Q/QSATF FOR INDICATED PARTICLE SIZES

    0.2500E-06   0.3500E-06   0.4500E-06   0.5500E-06   0.7000E-06   0.9000E-06   0.1100E-05   0.1300E-05
 1   1.0360        1.0360       1.0360       1.0360       1.0360       1.0360       1.0360       1.0360
 2   1.6777        1.6491       1.6048       1.5613       1.5044       1.4447       1.3993       1.3643
 3   1.8871        1.8326       1.7664       1.7056       1.6295       1.5522       1.4947       1.4509
 4   2.0124        1.9405       1.8605       1.7890       1.7013       1.6134       1.5488       1.4997
 5   2.1020        2.0172       1.9271       1.8480       1.7520       1.6567       1.5870       1.5342
 6   2.1715        2.0764       1.9785       1.8935       1.7911       1.6901       1.6164       1.5608
 7   2.2249        2.1208       2.0161       1.9262       1.8183       1.7125       1.6356       1.5776
 8   2.2703        2.1586       2.0483       1.9541       1.8417       1.7318       1.6522       1.5921
 9   2.3098        2.1915       2.0762       1.9784       1.8622       1.7488       1.6668       1.6050
10   2.3446        2.2205       2.1010       2.0000       1.8804       1.7639       1.6798       1.6165
11   2.3758        2.2466       2.1232       2.0194       1.8967       1.7776       1.6915       1.6269
12   2.4040        2.2701       2.1433       2.0370       1.9115       1.7899       1.7022       1.6363

    0.1600E-05   0.2000E-05   0.2600E-05   0.3500E-05   0.5000E-05   0.8000E-05   0.1500E-04
 1   1.0360        1.0360       1.0360       1.0360       1.0360       1.0360       1.0360
 2   1.3251        1.2889       1.2540       1.2226       1.1918       1.1569       1.1178
 3   1.4022        1.3571       1.3129       1.2717       1.2303       1.1844       1.1352
 4   1.4454        1.3949       1.3450       1.2979       1.2504       1.1982       1.1435
 5   1.4758        1.4215       1.3675       1.3162       1.2644       1.2080       1.1494
 6   1.4992        1.4419       1.3847       1.3302       1.2752       1.2155       1.1541
 7   1.5134        1.4536       1.3939       1.3369       1.2796       1.2178       1.1541
 8   1.5257        1.4638       1.4019       1.3369       1.2796       1.2178       1.1541
 9   1.5366        1.4729       1.4091       1.3369       1.2796       1.2178       1.1541
10   1.5464        1.4811       1.4157       1.3369       1.2796       1.2178       1.1541
11   1.5553        1.4886       1.4157       1.3369       1.2796       1.2178       1.1541
12   1.5634        1.4886       1.4157       1.3369       1.2796       1.2178       1.1541
```

```
CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT

INCREMENT        CHARGE FOR INDICATED PARTICLE SIZES

      0.2500E-06    0.3500E-06    0.4500E-06    0.5500E-06    0.7000E-06    0.9000E-06    0.1100E-05    0.1300E-05
 1   0.18895E-17   0.33413E-17   0.52363E-17   0.75764E-17   0.11922E-16   0.19280E-16   0.28423E-16   0.39355E-16
 2   0.30598E-17   0.53183E-17   0.81110E-17   0.11417E-16   0.17313E-16   0.26885E-16   0.38391E-16   0.51823E-16
 3   0.34418E-17   0.59103E-17   0.89279E-17   0.12473E-16   0.18752E-16   0.28884E-16   0.41007E-16   0.55113E-16
 4   0.36703E-17   0.62583E-17   0.94032E-17   0.13083E-16   0.19578E-16   0.30024E-16   0.42490E-16   0.56969E-16
 5   0.38336E-17   0.65055E-17   0.97398E-17   0.13514E-16   0.20161E-16   0.30829E-16   0.43539E-16   0.58280E-16
 6   0.39604E-17   0.66967E-17   0.99997E-17   0.13847E-16   0.20612E-16   0.31450E-16   0.44346E-16   0.59289E-16
 7   0.40579E-17   0.68398E-17   0.10190E-16   0.14086E-16   0.20925E-16   0.31868E-16   0.44872E-16   0.59926E-16
 8   0.41407E-17   0.69617E-17   0.10352E-16   0.14290E-16   0.21194E-16   0.32228E-16   0.45327E-16   0.60479E-16
 9   0.42126E-17   0.70677E-17   0.10494E-16   0.14468E-16   0.21430E-16   0.32544E-16   0.45727E-16   0.60967E-16
10   0.42762E-17   0.71614E-17   0.10619E-16   0.14626E-16   0.21639E-16   0.32825E-16   0.46085E-16   0.61403E-16
11   0.43331E-17   0.72453E-17   0.10731E-16   0.14768E-16   0.21827E-16   0.33078E-16   0.46407E-16   0.61798E-16
12   0.43845E-17   0.73213E-17   0.10833E-16   0.14896E-16   0.21997E-16   0.33309E-16   0.46701E-16   0.62158E-16

      0.1600E-05    0.2000E-05    0.2600E-05    0.3500E-05    0.5000E-05    0.8000E-05    0.1500E-04
 1   0.59103E-16   0.91693E-16   0.15399E-15   0.27760E-15   0.56409E-15   0.14388E-14   0.50445E-14
 2   0.75592E-16   0.11407E-15   0.18639E-15   0.32759E-15   0.64889E-15   0.16067E-14   0.54428E-14
 3   0.79991E-16   0.12011E-15   0.19514E-15   0.34076E-15   0.66989E-15   0.16449E-14   0.55276E-14
 4   0.82454E-16   0.12345E-15   0.19991E-15   0.34776E-15   0.68079E-15   0.16641E-14   0.55677E-14
 5   0.84191E-16   0.12581E-15   0.20325E-15   0.35267E-15   0.68844E-15   0.16777E-14   0.55967E-14
 6   0.85527E-16   0.12761E-15   0.20581E-15   0.35643E-15   0.69431E-15   0.16881E-14   0.56193E-14
 7   0.86334E-16   0.12865E-15   0.20717E-15   0.35822E-15   0.69668E-15   0.16913E-14   0.56193E-14
 8   0.87038E-16   0.12955E-15   0.20837E-15   0.35822E-15   0.69668E-15   0.16913E-14   0.56193E-14
 9   0.87662E-16   0.13036E-15   0.20940E-15   0.35822E-15   0.69668E-15   0.16913E-14   0.56193E-14
10   0.88221E-16   0.13109E-15   0.21041E-15   0.35822E-15   0.69668E-15   0.16913E-14   0.56193E-14
11   0.88727E-16   0.13174E-15   0.21041E-15   0.35822E-15   0.69668E-15   0.16913E-14   0.56193E-14
12   0.89189E-16   0.13174E-15   0.21041E-15   0.35822E-15   0.69668E-15   0.16913E-14   0.56193E-14
```

```
PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  1 OF CORRECTION PARAMETERS

   SIZE      CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W      COR. P
 2.500E-07  1.590  0.000   0.0009       0.0005       87.2518      8.381  12.7482   87.2518    8.381     12.7482
 3.500E-07  1.414  0.400   1.7859       1.1202       87.3555      8.414  12.6445   86.8819    8.264     13.1181
 4.500E-07  1.320  0.600   2.5381       1.6050       88.0199      8.634  11.9801   87.4690    8.451     12.5310
 5.500E-07  1.261  1.667   6.4831       4.0240       88.9860      8.976  11.0140   88.6923    8.869     11.3077
 7.000E-07  1.205  5.000  17.2301      10.7313       90.2408      9.468   9.7592   89.9461    9.347     10.0539
 9.000E-07  1.159  4.933  14.2047       9.0357       91.8451     10.199   8.1549   91.4197    9.992      8.5803
 1.100E-06  1.130  5.000  12.1443       7.9052       93.1214     10.891   6.8786   92.5937   10.590      7.4063
 1.300E-06  1.110  3.733   7.6527       5.2837       94.1943     11.581   5.8057   93.3696   11.041      6.6304
 1.600E-06  1.090  8.000  13.0744       9.4199       95.3716     12.503   4.6284   94.4841   11.790      5.5159
 2.000E-06  1.072  6.667   8.1804       6.6204       96.5251     13.670   3.4749   95.3483   12.483      4.6517
 2.600E-06  1.055 10.667   8.7944       8.7947       97.6651     15.287   2.3349   96.1378   13.240      3.8622
 3.500E-06  1.041 10.667   5.4164       7.4037       98.5620     17.259   1.4380   96.7487   13.940      3.2513
 5.000E-06  1.029 11.333   2.3183       8.1639       99.4207     20.959   0.5793   96.6255   13.789      3.3745
 8.000E-06  1.018 12.000   0.1755       8.4692       99.9586     31.694   0.0414   96.6939   13.872      3.3061
 1.500E-05  1.010 19.333   0.0007      11.4226       99.9999     56.257   0.0001   97.2323   14.595      2.7677

    EFFICIENCY - STATED = 92.50      COMPUTED = 92.4959     CONVERGENCE OBTAINED


    ADJUSTED NO-RAP EFF. =  97.1680
    MMD OF INLET SIZE DISTRIBUTION =  3.300E+00
    SIGMAP OF INLET SIZE DISTRIBUTION =  2.164E+00
    LOG-NORMAL GOODNESS OF FIT =  0.934
    MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.296E+00
    SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.628E+00
    LOG-NORMAL GOODNESS OF FIT =  0.961
    PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 14.502


    SIGMAG=    0.000  WITH  0.000 SNEAKAGE OVER    4.000  STAGES
    NTEMP = 1
    RMMD =  6.00
    RSIGMA = 2.50
    CORR. EFF. =  95.3156
    CORRECTED MMD OF EFFLUENT =  2.354E+00
    CORRECTED SIGMAP OF EFFLUENT =  2.154E+00
    LOG-NORMAL GOODNESS OF FIT =  0.915
    CORRECTED PRECIPITATION RATE PARAMETER =    12.45
```

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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP             RAPPING PUFF       NO-RAP+RAP PUFF     RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)   EFFICIENCY(%)     DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 3.605E+00           5.877E+01           5.433E-05            1.722E-03            1.776E-03          4.360E-02         2.500E-07
 3.877E+00           6.144E+01           1.519E-01            5.690E-03            1.576E-01          1.022E-01         3.500E-07
 4.212E+00           6.448E+01           2.783E-01            1.280E-02            2.911E-01          1.784E-01         4.500E-07
 4.568E+00           6.746E+01           8.701E-01            2.320E-02            8.933E-01          2.642E-01         5.500E-07
 5.118E+00           7.157E+01           1.466E+00            4.427E-02            1.510E+00          7.953E-01         7.000E-07
 5.861E+00           7.632E+01           1.558E+00            8.127E-02            1.639E+00          1.132E+00         9.000E-07
 6.609E+00           8.029E+01           1.630E+00            1.251E-01            1.755E+00          1.424E+00         1.100E-06
 7.358E+00           8.361E+01           1.215E+00            1.726E-01            1.387E+00          1.661E+00         1.300E-06
 8.483E+00           8.757E+01           1.273E+00            2.441E-01            1.517E+00          3.831E+00         1.600E-06
 9.978E+00           9.139E+01           9.975E-01            3.378E-01            1.335E+00          4.234E+00         2.000E-06
 1.221E+01           9.503E+01           6.939E-01            4.939E-01            1.148E+00          8.791E+00         2.600E-06
 1.548E+01           9.777E+01           4.607E-01            5.810E-01            1.042E+00          1.044E+01         3.500E-06
 2.096E+01           9.942E+01           1.399E-01            6.750E-01            8.150E-01          1.709E+01         5.000E-06
 3.169E+01           9.996E+01           8.405E-03            6.627E-01            6.711E-01          2.114E+01         8.000E-06
 5.626E+01           1.000E+02           2.390E-05            6.670E-01            6.670E-01          2.887E+01         1.500E-05
```

```
*****************************************************************************************************
*                                                                                                   *
*                               SUMMARY TABLE OF ESP OPERATING                                      *
*                                PARAMETERS AND PERFORMANCE                                         *
*                                                                                                   *
*                                                                                                   *
*                                    DATA SET NUMBER   1                                            *
*                                                                                                   *
*    ESP PERFORMANCE:     EFFICIENCY =  95.3156 %     SCA =  2.458E+01 M**2/(M**3/SEC)              *
*                                                                                                   *
*    ELECTRICAL CONDITIONS:      AVG. APPLIED VOLTAGE =  4.515E+04 V                                *
*                                                                                                   *
*                                AVG. CURRENT DENSITY =   25.81 NA/CM**2                            *
*                                                                                                   *
*                                RESISTIVITY =  1.000E+09 OHM-CM                                    *
*                                                                                                   *
*    SIZE DISTRIBUTIONS:      INLET MMD =  3.300E+00 UM     INLET SIGMAP =  2.164E+00               *
*                                                                                                   *
*                             OUTLET MMD =  2.354E+00 UM     OUTLET SIGMAP =  2.154E+00             *
*                                                                                                   *
*    NONIDEAL PARAMETERS:      GAS SNEAKAGE FRACTION = 0.00 /SECTION     GAS VELOCITY SIGMAG = 0.00 *
*                                                                                                   *
*                              RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00          *
*                                                                                                   *
*****************************************************************************************************
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PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO. 2 OF CORRECTION PARAMETERS

   SIZE       CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W     COR. P
2.500E-07  1.590  0.000   0.0007        0.0005     83.5792     7.351   16.4208   83.5792    7.351     16.4208
3.500E-07  1.414  0.400   1.4492        1.0109     83.6436     7.367   16.3564   83.0869    7.231     16.9131
4.500E-07  1.320  0.600   2.0818        1.4625     84.3356     7.543   15.6644   83.6881    7.378     16.3119
5.500E-07  1.261  1.667   5.3981        3.7277     85.3804     7.824   14.6196   85.0353    7.729     14.9647
7.000E-07  1.205  5.000  14.6749       10.1592     86.7494     8.224   13.2506   86.4029    8.119     13.5971
9.000E-07  1.159  4.933  12.5146        8.8115     88.5465     8.817   11.4535   88.0464    8.643     11.9536
1.100E-06  1.130  5.000  11.0687        7.9308     90.0056     9.371    9.9944   89.3853    9.126     10.6147
1.300E-06  1.110  3.733   7.2247        5.4148     91.2624     9.918    8.7376   90.2931    9.490      9.7069
1.600E-06  1.090  8.000  12.9907       10.0111     92.6688    10.632    7.3312   91.6256   10.091      8.3744
2.000E-06  1.072  6.667   8.7171        7.2589     94.0970    11.514    5.9030   92.7138   10.657      7.2862
2.600E-06  1.055 10.667  10.4449        9.9081     95.5793    12.690    4.4207   93.7840   11.303      6.2160
3.500E-06  1.041 10.667   7.5515        8.4919     96.8039    14.010    3.1961   94.6725   11.931      5.3275
5.000E-06  1.029 11.333   4.5396        8.6265     98.1916    16.327    1.8084   94.9061   12.113      5.0939
8.000E-06  1.018 12.000   1.0716        7.6040     99.5968    22.434    0.4032   95.7595   12.859      4.2405
1.500E-05  1.010 19.333   0.2721        9.5816     99.9364    29.951    0.0636   96.6833   13.859      3.3167

    EFFICIENCY - STATED = 92.50      COMPUTED = 92.4959      CONVERGENCE OBTAINED

    ADJUSTED NO-RAP EFF. =  95.4853
    MMD OF INLET SIZE DISTRIBUTION =  3.300E+00
    SIGMAP OF INLET SIZE DISTRIBUTION =  2.164E+00
    LOG-NORMAL GOODNESS OF FIT =  0.934
    MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.486E+00
    SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.719E+00
    LOG-NORMAL GOODNESS OF FIT =  0.961
    PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 12.604

    SIGMAG=    0.100  WITH  0.100 SNEAKAGE OVER    4.000  STAGES
    NTEMP = 1
    RMMD =  6.00
    RSIGMA = 2.50
    CORR. EFF. =  93.3079
    CORRECTED MMD OF EFFLUENT =  2.315E+00
    CORRECTED SIGMAP OF EFFLUENT =  2.099E+00
    LOG-NORMAL GOODNESS OF FIT =  0.925
    CORRECTED PRECIPITATION RATE PARAMETER =   11.00
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED         NO-RAP            RAPPING PUFF      NO-RAP+RAP PUFF     RAPPING PUFF     PARTICLE
MIG. VEL.(CM/SEC)    EFFICIENCY(%)    DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
  3.605E+00           5.877E+01          6.999E-05          2.024E-03          2.094E-03         4.360E-02        2.500E-07
  3.877E+00           6.144E+01          1.965E-01          6.688E-03          2.032E-01         1.022E-01        3.500E-07
  4.212E+00           6.448E+01          3.639E-01          1.504E-02          3.790E-01         1.784E-01        4.500E-07
  4.568E+00           6.746E+01          1.155E+00          2.727E-02          1.182E+00         2.642E-01        5.500E-07
  5.118E+00           7.157E+01          1.990E+00          5.203E-02          2.042E+00         7.953E-01        7.000E-07
  5.861E+00           7.632E+01          2.188E+00          9.552E-02          2.283E+00         1.132E+00        9.000E-07
  6.609E+00           8.029E+01          2.368E+00          1.470E-01          2.515E+00         1.424E+00        1.100E-06
  7.358E+00           8.361E+01          1.828E+00          2.028E-01          2.031E+00         1.661E+00        1.300E-06
  8.483E+00           8.757E+01          2.016E+00          2.869E-01          2.303E+00         3.831E+00        1.600E-06
  9.978E+00           9.139E+01          1.695E+00          3.971E-01          2.092E+00         4.234E+00        2.000E-06
  1.221E+01           9.503E+01          1.314E+00          5.335E-01          1.847E+00         8.791E+00        2.600E-06
  1.548E+01           9.777E+01          1.024E+00          6.829E-01          1.707E+00         1.044E+01        3.500E-06
  2.096E+01           9.942E+01          4.368E-01          7.935E-01          1.230E+00         1.709E+01        5.000E-06
  3.169E+01           9.996E+01          8.184E-02          7.789E-01          8.607E-01         2.114E+01        8.000E-06
  5.626E+01           1.000E+02          1.532E-02          7.840E-01          7.993E-01         2.887E+01        1.500E-05
```

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*******************************************************************************************
*                                                                                         *
*                               SUMMARY TABLE OF ESP OPERATING                            *
*                                PARAMETERS AND PERFORMANCE                               *
*                                                                                         *
*                                                                                         *
*                                     DATA SET NUMBER   2                                 *
*                                                                                         *
*       ESP PERFORMANCE:     EFFICIENCY =  93.3079 %     SCA =  2.458E+01 M**2/(M**3/SEC) *
*                                                                                         *
*       ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.515E+04 V                    *
*                                                                                         *
*                                  AVG. CURRENT DENSITY =   25.81 NA/CM**2                *
*                                                                                         *
*                                  RESISTIVITY =  1.000E+09 OHM*CM                        *
*                                                                                         *
*       SIZE DISTRIBUTIONS:     INLET MMD =  3.300E+00 UM     INLET SIGMAP =  2.164E+00   *
*                                                                                         *
*                               OUTLET MMD =  2.315E+00 UM     OUTLET SIGMAP =  2.099E+00 *
*                                                                                         *
*       NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.10 /SECTION     GAS VELOCITY SIGMAG = 0.10 *
*                                                                                         *
*                                RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00 *
*                                                                                         *
*******************************************************************************************
STOP  011111
```

APPENDIX H

OUTPUT DATA FOR EXAMPLE 1 (REVISION 1)

```
                    ****************************************
                    *                                      *
                    *          E.P.A. ESP MODEL            *
                    *   I.E.R.L.-R.T.P. AND SO.R.I.        *
                    *     REVISION I,JAN. 1. 1978          *
                    *                                      *
                    ****************************************

PRINTOUT OF INPUT DATA FOR DATA SET NUMBER  1


DATA ON CARD NUMBER   1

NENDPT = 16   NDATA =  1

DATA ON CARD NUMBER   2

LAB ESP; SCA=125FT2/1000ACFM;J=24.0UA/FT2

DATA ON CARD NUMBER   3

NEST =  1  NDIST =  1  NVI =  1  NX = 10  NY = 10  NITER =  3  NCALC =  0  NRAPD =  1  NEFF =  1  NTEMP =  1  NONID =  2

DATA ON CARD NUMBER   4

NN = 10  NUMINC = 20

DATA ON CARD NUMBER   5

DL =  0.01500 GRN/ACF  PL =  10.0000 FT  ETAO = 99.00000 %  DD =  1000.00 KG/M**3  EPS =  5.100E+00
VRATIO =   1.0300  UB = 0.000165 M**2/V-SEC  FPATH =   1.0000  EBD = 1500000. V/M  RHOCBS =  1.00E+09 OHM-CM

DATA ON CARD NUMBER   6

ABNUCK( 1) = 0.00  AZIGGY( 1) = 0.00  AZNUMB( 1) =  4.0
ABNUCK( 2) = 0.10  AZIGGY( 2) = 0.10  AZNUMB( 2) =  4.0


DATA ON CARD NUMBER   7
```

```
ENDPT( 1) =    0.200 UM   ENDPT( 2) =    0.300 UM   ENDPT( 3) =    0.400 UM   ENDPT( 4) =    0.500 UM   ENDPT( 5) =    0.600 UM
ENDPT( 6) =    0.800 UM   ENDPT( 7) =    1.000 UM   ENDPT( 8) =    1.200 UM   ENDPT( 9) =    1.400 UM   ENDPT(10) =    1.800 UM

DATA ON CARD NUMBER   8

ENDPT(11) =    2.200 UM   ENDPT(12) =    3.000 UM   ENDPT(13) =    4.000 UM   ENDPT(14) =    6.000 UM   ENDPT(15) =   10.000 UM
ENDPT(16) =   20.000 UM

DATA ON CARD NUMBER   9

PRCU( 1) =   0.0000 %   PRCU( 2) =   0.0002 %   PRCU( 3) =   0.4002 %   PRCU( 4) =   1.0002 %   PRCU( 5) =   2.6672 %
PRCU( 6) =   7.6672 %   PRCU( 7) =  12.6002 %   PRCU( 8) =  17.6002 %   PRCU( 9) =  21.3332 %   PRCU(10) =  29.3332 %

DATA ON CARD NUMBER  10

PRCU(11) =  36.0002 %   PRCU(12) =  46.6672 %   PRCU(13) =  57.3342 %   PRCU(14) =  68.6672 %   PRCU(15) =  80.6672 %
PRCU(16) = 100.0000 %

DATA ON CARD NUMBER  11

NUMSEC =  3    LSECT( 1) =  3  LSECT( 2) =  3  LSECT( 3) =  6

DATA ON CARD NUMBER  12

AS( 1) =  6.2500E+00 FT**2  VOS( 1) =  4.6000E+04 V  TCS( 1) =  1.5000E-04 A  WLS( 1) =  6.2500E+00 FT
ACS( 1) =  4.6875E-02 IN  BS( 1) =  5.0000E+00 IN  NWS( 1) =  5.0000E+00

DATA ON CARD NUMBER  13

SYS( 1) =  2.5000E+00 IN  VGS( 1) =  2.0000E+02 FT**3/MIN  VGASS( 1) =  3.2000E+00 FT/SEC  TEMPS( 1) =  7.6800E+01 F
PS( 1) =  1.0000E+00 ATM  VISS( 1) =  1.8000E-05 KG/M-SEC  LINCS( 1) =  8.3333E-01 FT

DATA ON CARD NUMBER  14

AS( 2) =  6.2500E+00 FT**2  VOS( 2) =  4.5800E+04 V  TCS( 2) =  1.5000E-04 A  WLS( 2) =  6.2500E+00 FT
ACS( 2) =  4.6875E-02 IN  BS( 2) =  5.0000E+00 IN  NWS( 2) =  5.0000E+00
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DATA ON CARD NUMBER  15

SYS( 2) =  2.5000E+00 IN  VGS( 2) =  2.0000E+02 FT**3/MIN  VGASS( 2) =  3.2000E+00 FT/SEC  TEMPS( 2) =  7.6800E+01 F
PS( 2) =  1.0000E+00 ATM  VISS( 2) =  1.8000E-05 KG/M-SEC  LINCS( 2) =  8.3333E-01 FT

DATA ON CARD NUMBER  16

AS( 3) =  1.2500E+01 FT**2  VOS( 3) =  4.4400E+04 V  TCS( 3) =  3.0000E-04 A  WLS( 3) =  1.2500E+01 FT
ACS( 3) =  4.6875E-02 IN  BS( 3) =  5.0000E+00 IN  NWS( 3) =  1.0000E+01

DATA ON CARD NUMBER  17

SYS( 3) =  2.5000E+00 IN  VGS( 3) =  2.0000E+02 FT**3/MIN  VGASS( 3) =  3.2000E+00 FT/SEC  TEMPS( 3) =  7.6800E+01 F
PS( 3) =  1.0000E+00 ATM  VISS( 3) =  1.8000E-05 KG/M-SEC  LINCS( 3) =  8.3333E-01 FT
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INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


LAB ESP: SCA=125FT2/1000ACFM;J=24.0UA/FT2

CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION APEA =  5.812E-01 M2        APPLIED VOLTAGE =  4.600F+04 VOLTS       TOTAL CURRENT =  1.500E-04 AMPS
WIRE TO PLATE =  1.270E-01 M           CORONA WIRE RADIUS =  1.191E-03 M        CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  7.869E-05 AMP/M           CURRENT DENSITY =  2.581E-04 AMP/M2      DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M        GAS FLOW RATE =  9.460E-02 M3/SEC        GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC        LENGTH INCR. =0.25416565 M               INPUT EFF./INCR. = 31.87

ROVRI     ERAVG        EPLT         AFID        CMCD      MMD        WEIGHT     DUST LAYER   J(PART)      J(ION)    INCR. NO.

1.0860   3.622E+05  2.7624E+05  2.2804E+13     25.8    6.69E-06   1.033E-05   3.027E-04   5.00E-08    2.58E-04        1
1.0501   3.622E+05  2.7455E+05  2.3583E+13     25.8    4.07E-06   6.545E-06   1.917E-04   6.06E-08    2.58E-04        2
1.0288   3.622E+05  2.7356E+05  2.4073E+13     25.8    2.89E-06   4.124E-06   1.208E-04   5.37E-08    2.58E-04        3

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2        APPLIED VOLTAGE =  4.580E+04 VOLTS       TOTAL CURRENT =  1.500E-04 AMPS
WIRE TO PLATE =  1.270E-01 M           CORONA WIRE RADIUS =  1.191E-03 M        CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  7.869E-05 AMP/M           CURRENT DENSITY =  2.581E-04 AMP/M2      DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M        GAS FLOW RATE =  9.460E-02 M3/SEC        GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MORILITY =  1.798E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC        LENGTH INCR. =0.25416565 M               INPUT EFF./INCR. = 31.87

ROVRI     ERAVG        EPLT         AFID        CMCD      MMD        WEIGHT     DUST LAYER   J(PART)      J(ION)    INCR. NO.

1.0165   3.606E+05  2.7206E+05  2.4470E+13     25.8    2.35E-06   2.836E-06   8.310E-05   4.64E-08    2.58E-04        4
1.0096   3.606E+05  2.7206E+05  2.4638E+13     25.8    2.04E-06   2.085E-06   6.107E-05   4.03E-08    2.58E-04        5
1.0056   3.606E+05  2.7206E+05  2.4736E+13     25.8    1.80E-06   1.589E-06   4.655E-05   3.49E-08    2.58E-04        6

CALCULATION IS IN SECTION NO. = 3 AND THF SECTION LENGTH IS =  1.5250 M

COLLECTION AREA =  1.162E+00 M2        APPLIED VOLTAGE =  4.440E+04 VOLTS       TOTAL CURRENT =  3.000E-04 AMPS
WIRE TO PLATE =  1.270E-01 M           CORONA WIRE RADIUS =  1.191E-03 M        CORONA WIRE LENGTH =  3.812E+00 M
CURRENT/M =  7.869E-05 AMP/M           CURRENT DENSITY =  2.581E-04 AMP/M2      DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M        GAS FLOW RATE =  9.460E-02 M3/SEC        GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC        LENGTH INCR. =0.25416565 M               INPUT EFF./INCR. = 31.87

ROVRI     ERAVG        EPLT         AFID        CMCD      MMD        WEIGHT     DUST LAYER   J(PART)      J(ION)    INCR. NO.

1.0031   3.496E+05  2.6452E+05  2.5578E+13     25.8    1.60E-06   1.206E-06   3.533E-05   2.93E-08    2.58E-04        7
1.0018   3.496E+05  2.6452E+05  2.5611E+13     25.8    1.50E-06   9.603E-07   2.813E-05   2.54E-08    2.58E-04        8
1.0011   3.496E+05  2.6452E+05  2.5631E+13     25.8    1.42E-06   7.745E-07   2.269E-05   2.21E-08    2.58E-04        9
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1.0006   3.496E+05  2.6452E+05  2.5642E+13    25.8   1.35E-06   6.304E-07   1.847E-05   1.92E-08     2.58E-04       10
1.0004   3.496E+05  2.6452E+05  2.5649E+13    25.8   1.27E-06   5.174E-07   1.516E-05   1.68E-08     2.58E-04       11
1.0002   3.496E+05  2.6452E+05  2.5653E+13    25.8   1.20E-06   4.272E-07   1.252E-05   1.46E-08     2.58E-04       12

EST. EFFICIENCY = 99.00     UNCORRECTED COMPUTED EFFICIENCY = 93.24

INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


LAB ESP: SCA=125FT2/1000ACFM;J=24.0UA/FT2


CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2          APPLIED VOLTAGE =  4.600E+04 VOLTS        TOTAL CURRENT =  1.500E-04 AMPS
WIRE TO PLATE =  1.270E-01 M             CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  7.869E-05 AMP/M             CURRENT DENSITY =  2.581E-04 AMP/M2       DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M          GAS FLOW RATE =  9.460E-02 M3/SEC         GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                  PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC    MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC          LENGTH INCR. =0.25416565 M                INPUT EFF./INCR. = 20.11

ROVRI     ERAVG        EPLT         AFID        CMCD       MMD         WEIGHT     DUST LAYER   J(PART)       J(ION)    INCR. NO.

1.0543   3.622E+05  2.7479E+05  2.3490E+13    25.8   6.71E-06   1.032E-05   3.022E-04   4.98E-08     2.58E-04        1
1.0371   3.622E+05  2.7395E+05  2.3879E+13    25.8   4.07E-06   6.541E-06   1.916E-04   6.06E-08     2.58E-04        2
1.0250   3.622E+05  2.7338E+05  2.4162E+13    25.8   2.89E-06   4.130E-06   1.210E-04   5.38E-08     2.58E-04        3

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2          APPLIED VOLTAGE =  4.580E+04 VOLTS        TOTAL CURRENT =  1.500E-04 AMPS
WIRE TO PLATE =  1.270E-01 M             CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  7.869E-05 AMP/M             CURRENT DENSITY =  2.581E-04 AMP/M2       DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M          GAS FLOW RATE =  9.460E-02 M3/SEC         GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                  PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC    MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC          LENGTH INCR. =0.25416565 M                INPUT EFF./INCR. = 20.11

ROVRI     ERAVG        EPLT         AFID        CMCD       MMD         WEIGHT     DUST LAYER   J(PART)       J(ION)    INCR. NO.

1.0168   3.606E+05  2.7208E+05  2.4463E+13    25.8   2.35E-06   2.842E-06   8.326E-05   4.65E-08     2.58E-04        4
1.0114   3.606E+05  2.7208E+05  2.4593E+13    25.8   2.04E-06   2.088E-06   6.117E-05   4.03E-08     2.58E-04        5
1.0078   3.606E+05  2.7208E+05  2.4682E+13    25.8   1.80E-06   1.591E-06   4.662E-05   3.49E-08     2.58E-04        6

CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  1.5250 M

COLLECTION AREA =  1.162E+00 M2          APPLIED VOLTAGE =  4.440E+04 VOLTS        TOTAL CURRENT =  3.000E-04 AMPS
WIRE TO PLATE =  1.270E-01 M             CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  3.812E+00 M
CURRENT/M =  7.869E-05 AMP/M             CURRENT DENSITY =  2.581E-04 AMP/M2       DEPOSIT E FIELD =  2.581E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M          GAS FLOW RATE =  9.460E-02 M3/SEC         GAS VELOCITY =  9.760E-01 M/SEC
TEMPERATURE = 297.667 K                  PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.798E-04 M2/VOLT-SEC    MEAN THERMAL SPEED =  4.439E+02 M/SEC     PART. PATH PARAM. =  5.708E-08 M
DUST WEIGHT =  3.250E-06 KG/SEC          LENGTH INCR. =0.25416565 M                INPUT EFF./INCR. = 20.11


ROVRI     ERAVG        EPLT         AFID        CMCD       MMD         WEIGHT     DUST LAYER   J(PART)       J(ION)    INCR. NO.
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1,0052  3.496E+05  2,6461E+05  2,5527E+13   25.8  1.60E-06  1,208E-06  3,538E-05  2,93E-08  2,58E-04   7
1,0036  3.496E+05  2,6461E+05  2,5568E+13   25.8  1.50E-06  9,615E-07  2,817E-05  2,54E-08  2,58E-04   8
1,0025  3.496E+05  2,6461E+05  2,5596E+13   25.8  1,42E-06  7,753E-07  2,271E-05  2,21E-08  2,58E-04   9
1,0017  3.496E+05  2,6461E+05  2,5615E+13   25.8  1,35E-06  6,310E-07  1,849E-05  1,92E-08  2,58E-04  10
1,0012  3.496E+05  2,6461E+05  2,5629E+13   25.8  1.27E-06  5,178E-07  1,517E-05  1,68E-08  2,58E-04  11
1,0008  3.496F+05  2,6461E+05  2,5638E+13   25.8  1.20E-06  4,275E-07  1,253E-05  1,46E-08  2,58E-04  12
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CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHARGN OR CHGSUM

SRI THEORY USED FOR PARTICLE CHARGING

INCREMENT NO.     Q/QSATF FOR INDICATED PARTICLE SIZES

    0.2500E-06   0.3500E-06   0.4500E-06   0.5500E-06   0.7000E-06   0.9000E-06   0.1100E-05   0.1300E-05
 1  1.0360         1.0360       1.0360       1.0360       1.0360       1.0360       1.0360       1.0360
 2  1.6765         1.6491       1.6069       1.5659       1.5128       1.4572       1.4146       1.3809
 3  1.8868         1.8344       1.7709       1.7129       1.6406       1.5667       1.5110       1.4676
 4  2.0127         1.9433       1.8663       1.7977       1.7136       1.6287       1.5653       1.5160
 5  2.1027         2.0207       1.9338       1.8577       1.7651       1.6724       1.6034       1.5501
 6  2.1726         2.0805       1.9859       1.9039       1.8047       1.7060       1.6328       1.5762
 7  2.2263         2.1253       2.0239       1.9369       1.8322       1.7285       1.6517       1.5926
 8  2.2719         2.1634       2.0564       1.9651       1.8558       1.7478       1.6682       1.6069
 9  2.3116         2.1966       2.0847       1.9897       1.8765       1.7648       1.6826       1.6195
10  2.3466         2.2259       2.1097       2.0116       1.8948       1.7800       1.6955       1.6307
11  2.3779         2.2521       2.1322       2.0312       1.9113       1.7936       1.7071       1.6409
12  2.4063         2.2759       2.1525       2.0489       1.9262       1.8059       1.7177       1.6501

    0.1600E-05   0.2000E-05   0.2600E-05   0.3500E-05   0.5000E-05   0.8000E-05   0.1500E-04
 1  1.0360         1.0360       1.0360       1.0360       1.0360       1.0360       0.9805
 2  1.3419         1.3037       1.2638       1.2246       1.1852       1.1440       1.0975
 3  1.4177         1.3692       1.3189       1.2699       1.2210       1.1704       1.1185
 4  1.4596         1.4052       1.3488       1.2942       1.2399       1.1839       1.1279
 5  1.4892         1.4305       1.3699       1.3113       1.2533       1.1935       1.1345
 6  1.5119         1.4499       1.3861       1.3245       1.2636       1.2009       1.1396
 7  1.5255         1.4609       1.3946       1.3307       1.2677       1.2032       1.1396
 8  1.5374         1.4706       1.4022       1.3307       1.2677       1.2032       1.1396
 9  1.5479         1.4793       1.4089       1.3307       1.2677       1.2032       1.1396
10  1.5573         1.4870       1.4089       1.3307       1.2677       1.2032       1.1396
11  1.5659         1.4941       1.4089       1.3307       1.2677       1.2032       1.1396
12  1.5737         1.4941       1.4089       1.3307       1.2677       1.2032       1.1396
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CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT

INCREMENT        CHARGE FOR INDICATED PARTICLE SIZES

         0.2500E-06    0.3500E-06    0.4500E-06    0.5500E-06    0.7000E-06    0.9000E-06    0.1100E-05    0.1300E-05
  1     0.18895E-17   0.33413E-17   0.52363E-17   0.75764E-17   0.11922E-16   0.19280E-16   0.28423E-16   0.39355E-16
  2     0.30576E-17   0.53184E-17   0.81218E-17   0.11451E-16   0.17409E-16   0.27117E-16   0.38808E-16   0.52455E-16
  3     0.34412E-17   0.59159E-17   0.89506E-17   0.12526E-16   0.18879E-16   0.29155E-16   0.41455E-16   0.55747E-16
  4     0.36708E-17   0.62673E-17   0.94325E-17   0.13147E-16   0.19720E-16   0.30309E-16   0.42942E-16   0.57586E-16
  5     0.38350E-17   0.65169E-17   0.97737E-17   0.13585E-16   0.20312E-16   0.31122E-16   0.43990E-16   0.58880E-16
  6     0.39624E-17   0.67099E-17   0.10037E-16   0.13923E-16   0.20768E-16   0.31747E-16   0.44795E-16   0.59875E-16
  7     0.40603E-17   0.68543E-17   0.10229E-16   0.14164E-16   0.21085E-16   0.32165E-16   0.45315E-16   0.60498E-16
  8     0.41436E-17   0.69772E-17   0.10393E-16   0.14370E-16   0.21356E-16   0.32526E-16   0.45766E-16   0.61039E-16
  9     0.42159E-17   0.70841E-17   0.10536E-16   0.14551E-16   0.21594E-16   0.32842E-16   0.46162E-16   0.61517E-16
 10     0.42797E-17   0.71786E-17   0.10663E-16   0.14710E-16   0.21805E-16   0.33123E-16   0.46516E-16   0.61944E-16
 11     0.43369E-17   0.72633E-17   0.10776E-16   0.14853E-16   0.21994E-16   0.33376E-16   0.46835E-16   0.62330E-16
 12     0.43886E-17   0.73399E-17   0.10879E-16   0.14983E-16   0.22166E-16   0.33607E-16   0.47125E-16   0.62682E-16

         0.1600E-05    0.2000E-05    0.2600E-05    0.3500E-05    0.5000E-05    0.8000E-05    0.1500E-04
  1     0.59103E-16   0.91693E-16   0.15399E-15   0.27760E-15   0.56409E-15   0.14388E-14   0.47743E-14
  2     0.76553E-16   0.11538E-15   0.18783E-15   0.32811E-15   0.64529E-15   0.15888E-14   0.53438E-14
  3     0.80874E-16   0.12118E-15   0.19602E-15   0.34026E-15   0.66482E-15   0.16255E-14   0.54458E-14
  4     0.83269E-16   0.12436E-15   0.20047E-15   0.34677E-15   0.67509E-15   0.16442E-14   0.54918E-14
  5     0.84954E-16   0.12660E-15   0.20361E-15   0.35136E-15   0.68237E-15   0.16575E-14   0.55241E-14
  6     0.86249E-16   0.12832E-15   0.20602E-15   0.35490E-15   0.68798E-15   0.16678E-14   0.55489E-14
  7     0.87025E-16   0.12930E-15   0.20728E-15   0.35657E-15   0.69025E-15   0.16710E-14   0.55489E-14
  8     0.87702E-16   0.13016E-15   0.20841E-15   0.35657E-15   0.69025E-15   0.16710E-14   0.55489E-14
  9     0.88302E-16   0.13092E-15   0.20941E-15   0.35657E-15   0.69025E-15   0.16710E-14   0.55489E-14
 10     0.88841E-16   0.13161E-15   0.20941E-15   0.35657E-15   0.69025E-15   0.16710E-14   0.55489E-14
 11     0.89329E-16   0.13223E-15   0.20941E-15   0.35657E-15   0.69025E-15   0.16710E-14   0.55489E-14
 12     0.89775E-16   0.13223E-15   0.20941E-15   0.35657E-15   0.69025E-15   0.16710E-14   0.55489E-14
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PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO. 1 OF CORRECTION PARAMETERS

  SIZE      CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W      COR. P
 2.500E-07 1.590  0.000   0.0010      0.0006     88.5687      8.824   11.4313   88.5687     8.824     11.4313
 3.500E-07 1.414  0.400   1.8884      1.1360     88.7009      8.872   11.2991   88.2556     8.715     11.7444
 4.500E-07 1.320  0.600   2.6661      1.6182     89.3651      9.118   10.6349   88.8470     8.925     11.1530
 5.500E-07 1.261  1.667   6.7526      4.0195     90.3050      9.495    9.6950   90.0288     9.381      9.9712
 7.000E-07 1.205  5.000  17.7324     10.5981     91.5119     10.036    8.4881   91.2347     9.905      8.7653
 9.000E-07 1.159  4.933  14.3956      8.8090     93.0155     10.829    6.9845   92.6155    10.602      7.3045
 1.100E-06 1.130  5.000  12.1546      7.6348     94.1818     11.572    5.8182   93.6856    11.239      6.3144
 1.300E-06 1.110  3.733   7.5813      5.0878     95.1393     12.304    4.8607   94.3638    11.702      5.6362
 1.600E-06 1.090  8.000  12.8201      9.0344     96.1645     13.268    3.8355   95.3300    12.467      4.6700
 2.000E-06 1.072  6.667   7.9521      6.3865     97.1453     14.469    2.8547   96.0386    13.137      3.9614
 2.600E-06 1.055 10.667   8.5246      8.6386     98.0873     16.099    1.9127   96.6510    13.820      3.3490
 3.500E-06 1.041 10.667   5.1979      7.4069     98.8337     18.112    1.1663   97.1285    14.446      2.8715
 5.000E-06 1.029 11.333   2.1822      8.4664     99.5391     21.890    0.4609   96.9107    14.148      3.0893
 8.000E-06 1.018 12.000   0.1505      8.9957     99.9700     33.002    0.0300   96.9000    14.134      3.1000
 1.500E-05 1.010 19.333   0.0008     12.1675     99.9999     58.252    0.0001   97.3973    14.846      2.6027

   EFFICIENCY - STATED = 93.24     COMPUTED = 93.2425     CONVERGENCE OBTAINED


   ADJUSTED NO-RAP EFF. =  97.6066
   MMD OF INLET SIZE DISTRIBUTION =  3.300E+00
   SIGMAP OF INLET SIZE DISTRIBUTION =  2.164E+00
   LOG-NORMAL GOODNESS OF FIT =  0.934
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.279E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.626E+00
   LOG-NORMAL GOODNESS OF FIT =  0.961
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 15.187


   SIGMAG=    0.000  WITH  0.000 SNEAKAGE OVER    4.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  95.8647
   CORRECTED MMD OF EFFLUENT =  2.407E+00
   CORRECTED SIGMAP OF EFFLUENT =  2.177E+00
   LOG-NORMAL GOODNESS OF FIT =  0.913
   CORRECTED PRECIPITATION RATE PARAMETER =   12.96
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP            RAPPING PUFF        NO-RAP+RAP PUFF      RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)   EFFICIENCY(%)     DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)   DIAM.(M)
 3.795E+00           6.066E+01          4.872E-05           1.619E-03           1.668E-03           4.360E-02        2.500E-07
 4.088E+00           6.339E+01          1.357E-01           5.350E-03           1.411E-01           1.022E-01        3.500E-07
 4.448E+00           6.649E+01          2.471E-01           1.204E-02           2.591E-01           1.784E-01        4.500E-07
 4.832E+00           6.950E+01          7.659E-01           2.182E-02           7.878E-01           2.642E-01        5.500E-07
 5.425E+00           7.364E+01          1.275E+00           4.163E-02           1.316E+00           7.953E-01        7.000E-07
 6.224E+00           7.834E+01          1.334E+00           7.642E-02           1.411E+00           1.132E+00        9.000E-07
 7.022E+00           8.220E+01          1.379E+00           1.176E-01           1.496E+00           1.424E+00        1.100E-06
 7.817E+00           8.536E+01          1.017E+00           1.623E-01           1.179E+00           1.661E+00        1.300E-06
 9.001E+00           8.905E+01          1.055E+00           2.295E-01           1.285E+00           3.831E+00        1.600E-06
 1.056E+01           9.254E+01          8.195E-01           3.177E-01           1.137E+00           4.234E+00        2.000E-06
 1.286E+01           9.576E+01          5.684E-01           4.268E-01           9.952E-01           8.791E+00        2.600E-06
 1.624E+01           9.815E+01          3.737E-01           5.463E-01           9.200E-01           1.044E+01        3.500E-06
 2.189E+01           9.954E+01          1.113E-01           6.348E-01           7.461E-01           1.709E+01        5.000E-06
 3.300E+01           9.997E+01          6.094E-03           6.231E-01           6.292E-01           2.114E+01        8.000E-06
 5.825E+01           1.000E+02          2.390E-05           6.272E-01           6.272E-01           2.887E+01        1.500E-05
```

```
*****************************************************************************************
*                                                                                       *
*                           SUMMARY TABLE OF ESP OPERATING                              *
*                            PARAMETERS AND PERFORMANCE                                 *
*                                                                                       *
*                                                                                       *
*                                DATA SET NUMBER   1                                    *
*                                                                                       *
*      ESP PERFORMANCE:     EFFICIENCY =  95,8647 %     SCA =  2,458E+01 M**2/(M**3/SEC) *
*                                                                                       *
*      ELECTRICAL CONDITIONS:     AVG, APPLIED VOLTAGE =  4,515E+04 V                   *
*                                 AVG, CURRENT DENSITY =   25,81 NA/CM**2               *
*                                 RESISTIVITY =  1,000E+09 OHM-CM                       *
*                                                                                       *
*      SIZE DISTRIBUTIONS:     INLET MMD =  3,300E+00 UM     INLET SIGMAP =  2,164E+00  *
*                              OUTLET MMD =  2,407E+00 UM     OUTLET SIGMAP =  2,177E+00 *
*                                                                                       *
*      NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0,00 /SECTION     GAS VELOCITY SIGMAG = 0,00 *
*                               RAPPING MMD =  6,000E+00 UM     RAPPING SIGMAP =  2,500E+00 *
*                                                                                       *
*****************************************************************************************
```

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PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  2 OF CORRECTION PARAMETERS

   SIZE      CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W      COR. P
2.500E-07  1.590  0.000   0.0008       0.0005      85.0413      7.730  14.9587   85.0413     7.730     14.9587
3.500E-07  1.414  0.400   1.5105       1.0237      85.1390      7.757  14.8610   84.6075     7.614     15.3925
4.500E-07  1.320  0.600   2.1586       1.4741      85.8414      7.954  14.1586   85.2230     7.780     14.7770
5.500E-07  1.261  1.667   5.5601       3.7294      86.8737      8.262  13.1263   86.5441     8.161     13.4559
7.000E-07  1.205  5.000  14.9759      10.0738      88.2127      8.700  11.7873   87.8819     8.587     12.1181
9.000E-07  1.159  4.933  12.6233       8.6511      89.9295      9.340  10.0705   89.4519     9.152     10.5481
1.100E-06  1.130  5.000  11.0645       7.7320      91.2913      9.931   8.7087   90.6989     9.664      9.3011
1.300E-06  1.110  3.733   7.1718       5.2670      92.4393     10.507   7.5607   91.5136    10.037      8.4864
1.600E-06  1.090  8.000  12.8182       9.7120      93.6944     11.245   6.3056   92.6982    10.648      7.3018
2.000E-06  1.072  6.667   8.5701       7.0716      94.9412     12.142   5.0588   93.6203    11.198      6.3797
2.600E-06  1.055 10.667  10.2993       9.7794      96.2002     13.306   3.7998   94.4858    11.791      5.5142
3.500E-06  1.041 10.667   7.4536       8.4866      97.2501     14.622   2.7499   95.2147    12.368      4.7853
5.000E-06  1.029 11.333   4.4961       8.8535      98.4387     16.925   1.5613   95.3013    12.442      4.6987
8.000E-06  1.018 12.000   1.0551       8.0015      99.6540     23.056   0.3460   95.9895    13.086      4.0105
1.500E-05  1.010 19.333   0.2420      10.1438      99.9507     30.987   0.0493   96.8441    14.061      3.1559

   EFFICIENCY - STATED = 93.24     COMPUTED = 93.2425     CONVERGENCE OBTAINED


   ADJUSTED NO-RAP EFF. =  96.0646
   MMD OF INLET SIZE DISTRIBUTION =  3.300E+00
   SIGMAP OF INLET SIZE DISTRIBUTION =  2.164E+00
   LOG-NORMAL GOODNESS OF FIT =  0.934
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.475E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.720E+00
   LOG-NORMAL GOODNESS OF FIT =  0.960
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 13.163


   SIGMAG=     0.100  WITH  0.100 SNEAKAGE OVER    4.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  93.9853
   CORRECTED MMD OF EFFLUENT =  2.354E+00
   CORRECTED SIGMAP OF EFFLUENT =  2.116E+00
   LOG-NORMAL GOODNESS OF FIT =  0.923
   CORRECTED PRECIPITATION RATE PARAMETER =   11.44
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP            RAPPING PUFF       NO-RAP+RAP PUFF     RAPPING PUFF     PARTICLE
MIG. VEL.(CM/SEC)   EFFICIENCY(%)    DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 3.795E+00            6.066E+01          6.375E-05          1.933E-03          1.996E-03          4.360E-02         2.500E-07
 4.088E+00            6.339E+01          1.785E-01          6.386E-03          1.849E-01          1.022E-01         3.500E-07
 4.448E+00            6.649E+01          3.290E-01          1.437E-02          3.433E-01          1.784E-01         4.500E-07
 4.832E+00            6.950E+01          1.037E+00          2.604E-02          1.063E+00          2.642E-01         5.500E-07
 5.425E+00            7.364E+01          1.770E+00          4.969E-02          1.820E+00          7.953E-01         7.000E-07
 6.224E+00            7.834E+01          1.924E+00          9.122E-02          2.015E+00          1.132E+00         9.000E-07
 7.022E+00            8.220E+01          2.064E+00          1.404E-01          2.204E+00          1.424E+00         1.100E-06
 7.817E+00            8.536E+01          1.582E+00          1.937E-01          1.776E+00          1.661E+00         1.300E-06
 9.001E+00            8.905E+01          1.734E+00          2.740E-01          2.008E+00          3.831E+00         1.600E-06
 1.056E+01            9.254E+01          1.452E+00          3.792E-01          1.831E+00          4.234E+00         2.000E-06
 1.286E+01            9.576E+01          1.129E+00          5.095E-01          1.639E+00          8.791E+00         2.600E-06
 1.624E+01            9.815E+01          8.810E-01          6.521E-01          1.533E+00          1.048E+01         3.500E-06
 2.189E+01            9.954E+01          3.771E-01          7.577E-01          1.135E+00          1.709E+01         5.000E-06
 3.300E+01            9.997E+01          7.024E-02          7.438E-01          8.140E-01          2.114E+01         8.000E-06
 5.825E+01            1.000E+02          1.187E-02          7.487E-01          7.605E-01          2.887E+01         1.500E-05
```

```
        ********************************************************************************************************************
        *                                                                                                                  *
        *                                                                                                                  *
        *                                       SUMMARY TABLE OF ESP OPERATING                                             *
        *                                        PARAMETERS AND PERFORMANCE                                                *
        *                                                                                                                  *
        *                                                                                                                  *
        *                                                                                                                  *
        *                                                                                                                  *
        *                                              DATA SET NUMBER   2                                                 *
        *                                                                                                                  *
        *                                                                                                                  *
        *            ESP PERFORMANCF:     EFFICIENCY =  93.9853 %   SCA =  2.458E+01 M**2/(M**3/SEC)                       *
        *                                                                                                                  *
        *                                                                                                                  *
        *            ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.515E+04 V                                        *
        *                                                                                                                  *
        *                                       AVG. CURRENT DENSITY =   25.81 NA/CM**2                                    *
        *                                                                                                                  *
        *                                       RESISTIVITY =  1.000E+09 OHM-CM                                            *
        *                                                                                                                  *
        *                                                                                                                  *
        *            SIZE DISTRIBUTIONS:     INLET MMD =  3.300E+00 UM     INLET SIGMAP =  2.164E+00                       *
        *                                                                                                                  *
        *                                    OUTLET MMD =  2.354E+00 UM     OUTLET SIGMAP =  2.116E+00                     *
        *                                                                                                                  *
        *                                                                                                                  *
        *            NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.10 /SECTION     GAS VELOCITY SIGMAG = 0.10         *
        *                                                                                                                  *
        *                                     RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00                  *
        *                                                                                                                  *
        *                                                                                                                  *
        ********************************************************************************************************************
STOP  011111
```

APPENDIX I

OUTPUT DATA FOR EXAMPLE 2 (REVISION 2)

```
                    ************************************
                    *                                  *
                    *         E.P.A. ESP MODEL         *
                    *                                  *
                    *   I.E.R.L.-R.T.P. AND SO.R.I.    *
                    *                                  *
                    *     REVISION II, AUG., 1979      *
                    *                                  *
                    ************************************

PRINTOUT OF INPUT DATA FOR DATA SET NUMBER  1


DATA ON CARD NUMBER   1

NENDPT = 16   NDATA =  1

DATA ON CARD NUMBER   2

LAB ESP; SCA=82FT2/1000ACFM;CALCULATED V-I FOR EACH ELECTRICAL SECTION

DATA ON CARD NUMBER   3

NEST =  1  NDIST =  1  NVI =  4  NX = 15  NY = 15  NITER =  1  NCALC =  0  NRAPD =  1  NEFF =  1  NTEMP =  1  NONID =  2

DATA ON CARD NUMBER   4

NN =  5  NUMINC =  3

DATA ON CARD NUMBER   5

IFINAL = 20  JI1 =  2  JI2 = 21  VISKIP = 1  VISAME =  2

DATA ON CARD NUMBER   6

DL =  0.06500 GRN/ACF  PL =  10.0000 FT  ETAO = 99.00000 %  DD =  1000.00 KG/M**3  EPS =  5.100E+00
VRATIO =   1.0300  US = 0.000165 M**2/V-SEC  FPATH =   1.0000  FBD = 1500000. V/M  RHOCGS =  1.00E+09 OHM-CM

DATA ON CARD NUMBER   7

ASNUCK( 1) = 0.00  AZIGGY( 1) = 0.00  AZNUMS( 1) =  4.0
```

```
ABMUCK( 2) = 0.10  AZIGGY( 2) = 0.10  AZNUMS( 2) =  4.0

DATA ON CARD NUMBFR   8

ENDPT( 1) =    0.200 UM   ENDPT( 2) =    0.300 UM   ENDPT( 3) =    0.400 UM   ENDPT( 4) =    0.500 UM   ENDPT( 5) =    0.600 UM
ENDPT( 6) =    0.800 UM   ENDPT( 7) =    1.000 UM   FNDPT( 8) =    1.200 UM   ENDPT( 9) =    1.400 UM   ENDPT(10) =    1.800 UM

DATA ON CARD NUMBER   9

ENDPT(11) =    2.200 UM   ENDPT(12) =    3.000 UM   ENDPT(13) =    4.000 UM   ENDPT(14) =    6.000 UM   FNDPT(15) =   10.000 UM
ENDPT(16) =   20.000 UM

DATA ON CARD NUMRFR  10

PRCU( 1) =   0.0000 %   PRCU( 2) =   0.0076 %   PRCU( 3) =   0.0563 %   PRCU( 4) =   0.2682 %   PRCU( 5) =   0.8652 %
PRCU( 6) =   2.9845 %   PRCU( 7) =   5.9695 %   PRCU( 8) =   9.5515 %   PRCU( 9) =  12.8350 %   PRCU(10) =  19.7004 %

DATA ON CARD NUMRFR  11

PRCU(11) =  26.8683 %   PRCU(12) =  38.8082 %   PRCU(13) =  49.2516 %   PRCU(14) =  64.1765 %   PRCU(15) =  79.1014 %
PRCU(16) = 100.0000 %

DATA ON CARD NUMBER  12

NUMSEC =  3    LSFCT( 1) =  6  LSECT( 2) =  6  LSECT( 3) = 12

DATA ON CARD NUMBER  13

AB( 1) =  6.2500F+00 FT**2  VOS( 1) =  4.0800E+04 V  TCS( 1) =  6.2500E-05 A  HLS( 1) =  6.2500E+00 FT
ACS( 1) =  4.6875E-02 IN  BS( 1) =  5.0000E+00 IN  HHS( 1) =  5.0000F+00

DATA ON CARD NUMBER  14

SYS( 1) =  2.5000F+00 IN  VGS( 1) =  3.0533F+02 FT**3/MIN  VGASS( 1) =  4.8853E+00 FT/SEC  TEMPS( 1) =  7.6000E+01 F
PS( 1) =  1.0000E+00 ATM  VISS( 1) =  1.8800F-05 KG/M-SFC  LINCS( 1) =  4.1667F-01 FT
```

```
DATA ON CARD NUMBER  15

RFS( 1) =  9.0000E-01  START1( 1) =  6.0000E-05 A/M**2  START2( 1) =  2.0000E-05 A/M**2

START3( 1) =  2.0000E-05 A/M**2  VSTAR( 1) =  3.8000E+04 V

DATA ON CARD NUMBER  16

AS( 2) =  6.2500E+00 FT**2  VOS( 2) =  4.0800E+04 V  TCS( 2) =  6.2500E-05 A  WLS( 2) =  6.2500E+00 FT

ACS( 2) =  4.6875E-02 IN  BS( 2) =  5.0000E+00 IN  NHS( 2) =  5.0000E+00

DATA ON CARD NUMBER  17

SYS( 2) =  2.5000E+00 IN  VGS( 2) =  3.0533E+02 FT**3/MIN  VGASS( 2) =  4.8853E+00 FT/SEC  TEMPS( 2) =  7.6000E+01 F

PS( 2) =  1.0000E+00 ATM  VISS( 2) =  1.8000E-05 KG/M-SEC  LINCS( 2) =  4.1667E-01 FT

DATA ON CARD NUMBER  18

RFS( 2) =  9.0000E-01  START1( 2) =  6.0000E-05 A/M**2  START2( 2) =  2.0000E-05 A/M**2

START3( 2) =  2.0000E-05 A/M**2  VSTAR( 2) =  3.8000E+04 V

DATA ON CARD NUMBER  19

AS( 3) =  1.2500E+01 FT**2  VOS( 3) =  3.9600E+04 V  TCS( 3) =  1.2500E-04 A  WLS( 3) =  1.2500E+01 FT

ACS( 3) =  4.6875E-02 IN  BS( 3) =  5.0000E+00 IN  NHS( 3) =  1.0000E+01

DATA ON CARD NUMBER  20

SYS( 3) =  2.5000E+00 IN  VGS( 3) =  3.0533E+02 FT**3/MIN  VGASS( 3) =  4.8853E+00 FT/SEC  TEMPS( 3) =  7.6000E+01 F

PS( 3) =  1.0000E+00 ATM  VISS( 3) =  1.8000E-05 KG/M-SEC  LINCS( 3) =  4.1667E-01 FT

DATA ON CARD NUMBER  21

RFS( 3) =  9.0000E-01  START1( 3) =  6.0000E-05 A/M**2  START2( 3) =  2.0000E-05 A/M**2

START3( 3) =  2.0000E-05 A/M**2  VSTAR( 3) =  3.8000E+04 V
```

```
CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  1

                    VW = -3.7698E+04  ACDNTY =  6.0000E-05  AEPLT = -1.7773E+05

                    VW = -3.8347E+04  ACDNTY =  8.0000E-05  AEPLT = -1.8647E+05

                    VW = -3.8965E+04  ACDNTY =  1.0000E-04  AEPLT = -1.9469E+05

                    VW = -3.9557E+04  ACDNTY =  1.2000E-04  AEPLT = -2.0248E+05

                    VW = -4.0125E+04  ACDNTY =  1.4000E-04  AEPLT = -2.0988E+05

                    VW = -4.0673E+04  ACDNTY =  1.6000E-04  AEPLT = -2.1697E+05

                    VW = -4.1204E+04  ACDNTY =  1.8000E-04  AEPLT = -2.2376E+05

                    VW = -4.0802E+04  ACDNTY =  1.6478E-04  AEPLT = -2.1861E+05


INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


LAB ESP; SCA=82FT2/1000ACFM;CALCULATED V-I FOR EACH ELECTRICAL SECTION

CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2          APPLIED VOLTAGE =  4.080E+04 VOLTS         TOTAL CURRENT =  9.578E-05 AMPS
WIRE TO PLATE =  1.270E-01 M             CORONA WIRE RADIUS =  1.191E-03 M          CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  5.024E-05 AMP/M             CURRENT DENSITY =  1.648E-04 AMP/M2        DEPOSIT E FIELD =  1.648E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M          GAS FLOW RATE =  1.484E-01 M3/SEC          GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                  PRESSURE =   1.000 ATM                     VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC    MEAN THERMAL SPEED =  4.436E+02 M/SEC      PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC          LENGTH INCR. =0.12708435 M                 INPUT EFF./INCR. = 17.46

RIOVR     ERAVG       EPLT        AFID        CMCD      MMD         WEIGHT      DUST LAYER   J(PART)      J(ION)    INCR. NO.

0.8198    2.056E+05   2.1861E+05  1.1808E+13    13.5    7.30E-06    5.885E-06   5.264E-04    3.53E-08     1.65E-04       1
0.7114    2.056E+05   2.1861E+05  1.1824E+13    11.7    4.42E-06    9.761E-06   8.731E-04    8.79E-08     1.65E-04       2
0.6884    2.056E+05   2.1861E+05  1.1826E+13    11.3    2.97E-06    1.010E-05   9.030E-04    1.11E-07     1.65E-04       3
0.6814    2.056E+05   2.1861E+05  1.1826E+13    11.2    2.28E-06    9.660E-06   8.640E-04    1.21E-07     1.65E-04       4
0.6804    2.056E+05   2.1861E+05  1.1826E+13    11.2    1.92E-06    8.978E-06   8.030E-04    1.24E-07     1.65E-04       5
0.6824    2.056E+05   2.1861E+05  1.1827E+13    11.2    1.63E-06    8.217E-06   7.350E-04    1.25E-07     1.65E-04       6
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                    CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  2

                              VW = -3.7498E+04  ACDNTY =  6.0000E-05  AEPLT = -1.7773E+05

                              VW = -3.8347E+04  ACDNTY =  8.0000E-05  AEPLT = -1.8647E+05

                              VW = -3.8965E+04  ACDNTY =  1.0000E-04  AEPLT = -1.9469E+05

                              VW = -3.9557E+04  ACDNTY =  1.2000E-04  AEPLT = -2.0248E+05

                              VW = -4.0125E+04  ACDNTY =  1.4000E-04  AEPLT = -2.0988E+05

                              VW = -4.0673E+04  ACDNTY =  1.6000E-04  AEPLT = -2.1697E+05

                              VW = -4.1204E+04  ACDNTY =  1.8000E-04  AEPLT = -2.2376E+05

                              VW = -4.0802E+04  ACDNTY =  1.6478E-04  AEPLT = -2.1861E+05

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2        APPLIED VOLTAGE =  4.080E+04 VOLTS        TOTAL CURRENT =  9.578E-05 AMPS
WIRE TO PLATE =  1.270E-01 M           CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  5.024E-05 AMP/M           CURRENT DENSITY =  1.648E-04 AMP/M2       DEPOSIT E FIELD =  1.648E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M        GAS FLOW RATE =  1.444E-01 M3/SEC         GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.436E+02 M/SEC     PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC        LENGTH INCR. =0.12708435 M                INPUT EFF./INCR. = 17.46

RIOVR     ERAVG       EPLT        APID       CMCD     MMD       WEIGHT     DUST LAYER  J(PART)      J(ION)   INCR. NO.

0.6862  2.056E+05  2.1861E+05  1.1827E+13   11.3  1.45E-06  7.460E-06  6.673E-04  1.23E-07   1.65E-04      7
0.6910  2.056E+05  2.1861E+05  1.1827E+13   11.4  1.32E-06  6.747E-06  6.035E-04  1.20E-07   1.65E-04      8
0.6965  2.056E+05  2.1861E+05  1.1827E+13   11.5  1.19E-06  6.093E-06  5.450E-04  1.17E-07   1.65E-04      9
0.7024  2.056E+05  2.1861E+05  1.1827E+13   11.6  1.08E-06  5.497E-06  4.917E-04  1.13E-07   1.65E-04     10
0.7085  2.056E+05  2.1861E+05  1.1827E+13   11.7  9.97E-07  4.962E-06  4.438E-04  1.09E-07   1.65E-04     11
0.7148  2.056E+05  2.1861E+05  1.1827E+13   11.8  9.31E-07  4.486E-06  4.013E-04  1.05E-07   1.65E-04     12

                    CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  3

                              VW = -3.7701E+04  ACDNTY =  6.0000E-05  AEPLT = -1.7777E+05

                              VW = -3.8350E+04  ACDNTY =  8.0000E-05  AEPLT = -1.8651E+05

                              VW = -3.8968E+04  ACDNTY =  1.0000E-04  AEPLT = -1.9473E+05
                              VW = -3.9560E+04  ACDNTY =  1.2000E-04  AEPLT = -2.0252E+05

                              VW = -4.0128E+04  ACDNTY =  1.4000E-04  AEPLT = -2.0993E+05

                              VW = -3.9601E+04  ACDNTY =  1.2142E-04  AEPLT = -2.0306E+05


CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  1.5250 M

COLLECTION AREA =  1.162E+00 M2        APPLIED VOLTAGE =  3.960E+04 VOLTS        TOTAL CURRENT =  1.412E-04 AMPS
WIRE TO PLATE =  1.270E-01 M           CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  3.812E+00 M
CURRENT/M =  3.702E-05 AMP/M           CURRENT DENSITY =  1.214E-04 AMP/M2       DEPOSIT E FIELD =  1.214E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M        GAS FLOW RATE =  1.444E-01 M3/SEC         GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.436E+02 M/SEC     PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC        LENGTH INCR. =0.12708435 M                INPUT EFF./INCR. = 17.46

RIOVR      ERAVG        EPLT          AFID        CMCD      MMD         WEIGHT      DUST LAYER   J(PART)       J(ION)   INCR. NO.

0.6684   1.963E+05  2.0306E+05  9.2745E+12    8.1    8.51E-07    3.784E-06    3.385E-04    9.33E-08     1.21E-04      13
0.6756   1.963E+05  2.0306E+05  9.2745E+12    8.2    8.03E-07    3.449E-06    3.085E-04    8.93E-08     1.21E-04      14
0.6829   1.963E+05  2.0306E+05  9.2745E+12    8.3    7.63E-07    3.150E-06    2.817E-04    8.52E-08     1.21E-04      15
0.6902   1.963E+05  2.0306E+05  9.2745E+12    8.4    7.31E-07    2.886E-06    2.581E-04    8.14E-08     1.21E-04      16
0.6975   1.963E+05  2.0306E+05  9.2745E+12    8.5    7.04E-07    2.652E-06    2.372E-04    7.77E-08     1.21E-04      17
0.7047   1.963E+05  2.0306E+05  9.2746E+12    8.6    6.78E-07    2.445E-06    2.187E-04    7.43E-08     1.21E-04      18
0.7118   1.963E+05  2.0306E+05  9.2746E+12    8.6    6.56E-07    2.260E-06    2.022E-04    7.10E-08     1.21E-04      19
0.7188   1.963E+05  2.0306E+05  9.2746E+12    8.7    6.38E-07    2.095E-06    1.874E-04    6.79E-08     1.21E-04      20
0.7257   1.963E+05  2.0306E+05  9.2746E+12    8.8    6.22E-07    1.947E-06    1.742E-04    6.50E-08     1.21E-04      21
0.7325   1.963E+05  2.0306E+05  9.2746E+12    8.9    6.09E-07    1.814E-06    1.622E-04    6.22E-08     1.21E-04      22
0.7391   1.963E+05  2.0306E+05  9.2746E+12    9.0    5.97E-07    1.693E-06    1.514E-04    5.96E-08     1.21E-04      23
0.7456   1.963E+05  2.0306E+05  9.2746E+12    9.1    5.87E-07    1.584E-06    1.416E-04    5.71E-08     1.21E-04      24

DESIGN EFFICIENCY = 99.00     UNCORRECTED COMPUTED EFFICIENCY = 79.01
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CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHARGN OR CHGSUM

SRI THEORY USED FOR PARTICLE CHARGING

INCREMENT NO.     Q/QSATF FOR INDICATED PARTICLE SIZFS

     0.2500E-06  0.3500E-06  0.4500E-06  0.5500E-06  0.7000E-06  0.9000E-06  0.1100E-05  0.1300E-05
  1  1.0663      1.0390      0.9995      0.9613      0.9116      0.8615      0.8720      0.7916
  2  1.3532      1.3082      1.2569      1.2112      1.1555      1.0976      1.0486      1.0102
  3  1.5070      1.4468      1.3840      1.3296      1.2644      1.1990      1.1481      1.1093
  4  1.6119      1.5398      1.4680      1.4068      1.3341      1.2625      1.2086      1.1680
  5  1.6913      1.6096      1.5305      1.4639      1.3852      1.3085      1.2517      1.2092
  6  1.7551      1.6654      1.5802      1.5090      1.4254      1.3443      1.2851      1.2410
  7  1.8084      1.7118      1.6214      1.5463      1.4584      1.3737      1.3123      1.2666
  8  1.8541      1.7515      1.6566      1.5780      1.4865      1.3986      1.3352      1.2882
  9  1.8941      1.7861      1.6871      1.6056      1.5108      1.4201      1.3549      1.3067
 10  1.9296      1.8168      1.7142      1.6300      1.5322      1.4390      1.3722      1.3229
 11  1.9616      1.8444      1.7385      1.6518      1.5514      1.4559      1.3876      1.3373
 12  1.9906      1.8694      1.7605      1.6716      1.5688      1.4711      1.4015      1.3502
 13  2.0095      1.8853      1.7742      1.6837      1.5792      1.4800      1.4094      1.3575
 14  2.0274      1.9003      1.7872      1.6951      1.5890      1.4884      1.4169      1.3643
 15  2.0443      1.9145      1.7995      1.7059      1.5983      1.4964      1.4240      1.3708
 16  2.0603      1.9280      1.8111      1.7162      1.6072      1.5039      1.4240      1.3708
 17  2.0756      1.9409      1.8222      1.7260      1.6156      1.5111      1.4240      1.3708
 18  2.0901      1.9531      1.8328      1.7354      1.6236      1.5111      1.4240      1.3708
 19  2.1040      1.9648      1.8429      1.7443      1.6236      1.5111      1.4240      1.3708
 20  2.1173      1.9760      1.8525      1.7528      1.6236      1.5111      1.4240      1.3708
 21  2.1300      1.9867      1.8618      1.7528      1.6236      1.5111      1.4240      1.3708
 22  2.1423      1.9970      1.8618      1.7528      1.6236      1.5111      1.4240      1.3708
 23  2.1540      2.0070      1.8618      1.7528      1.6236      1.5111      1.4240      1.3708
 24  2.1654      2.0070      1.8618      1.7528      1.6236      1.5111      1.4240      1.3708

     0.1600E-05  0.2000E-05  0.2600E-05  0.3500E-05  0.5000E-05  0.8000E-05  0.1500E-04
  1  0.7564      0.7216      0.6866      0.6534      0.6227      0.5910      0.5508
  2  0.9665      0.9233      0.8795      0.8392      0.8019      0.7571      0.6984
  3  1.0651      1.0195      0.9729      0.9302      0.8872      0.8368      0.7690
  4  1.1226      1.0780      1.0341      0.9917      0.9489      0.8916      0.8173
  5  1.1623      1.1175      1.0741      1.0362      0.9944      0.9377      0.8523
  6  1.1925      1.1471      1.1035      1.0660      1.0305      0.9751      0.8794
  7  1.2168      1.1706      1.1266      1.0891      1.0549      1.0055      0.9047
  8  1.2370      1.1899      1.1455      1.1077      1.0740      1.0316      0.9293
  9  1.2543      1.2064      1.1613      1.1232      1.0895      1.0501      0.9537
 10  1.2694      1.2207      1.1750      1.1363      1.1024      1.0646      0.9740
 11  1.2828      1.2333      1.1869      1.1477      1.1133      1.0762      0.9912
 12  1.2948      1.2446      1.1975      1.1577      1.1228      1.0859      1.0069
 13  1.3013      1.2505      1.2029      1.1624      1.1269      1.0894      1.0160
 14  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0235
 15  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0297
 16  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0351
 17  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0397
 18  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0397
 19  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0397
 20  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0397
 21  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0397
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22  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0397
23  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0397
24  1.3075      1.2505      1.2029      1.1624      1.1269      1.0894      1.0397
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CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT

INCREMENT       CHARGE FOR INDICATED PARTICLE SIZES

          0.2500E-06    0.3500E-06    0.4500E-06    0.5500E-06    0.7000E-06    0.9000E-06    0.1100E-05    0.1300E-05
   1     0.17422E-17   0.30023E-17   0.45269E-17   0.63002E-17   0.94017E-17   0.14369E-16   0.20212E-16   0.26950E-16
   2     0.22111E-17   0.37803E-17   0.56927E-17   0.79380E-17   0.11917E-16   0.18306E-16   0.25784E-16   0.34393E-16
   3     0.24623E-17   0.41808E-17   0.62682E-17   0.87137E-17   0.13040E-16   0.19998E-16   0.28232E-16   0.37769E-16
   4     0.26336E-17   0.44497E-17   0.66487E-17   0.92196E-17   0.13759E-16   0.21057E-16   0.29718E-16   0.39765E-16
   5     0.27634E-17   0.46514E-17   0.69320E-17   0.95935E-17   0.14286E-16   0.21823E-16   0.30779E-16   0.41171E-16
   6     0.28676E-17   0.48126E-17   0.71572E-17   0.98893E-17   0.14700E-16   0.22422E-16   0.31600E-16   0.42251E-16
   7     0.29547E-17   0.49467E-17   0.73437E-17   0.10134E-16   0.15041E-16   0.22912E-16   0.32268E-16   0.43125E-16
   8     0.30294E-17   0.50613E-17   0.75028E-17   0.10342E-16   0.15331E-16   0.23326E-16   0.32831E-16   0.43858E-16
   9     0.30947E-17   0.51614E-17   0.76414E-17   0.10522E-16   0.15582E-16   0.23684E-16   0.33316E-16   0.44489E-16
  10     0.31528E-17   0.52501E-17   0.77641E-17   0.10682E-16   0.15803E-16   0.24000E-16   0.33742E-16   0.45040E-16
  11     0.32050E-17   0.53298E-17   0.78740E-17   0.10825E-16   0.16001E-16   0.24282E-16   0.34121E-16   0.45530E-16
  12     0.32525E-17   0.54020E-17   0.79737E-17   0.10955E-16   0.16180E-16   0.24536E-16   0.34463E-16   0.45971E-16
  13     0.32834E-17   0.54481E-17   0.80359E-17   0.11034E-16   0.16287E-16   0.24684E-16   0.34657E-16   0.46217E-16
  14     0.33126E-17   0.54915E-17   0.80946E-17   0.11109E-16   0.16388E-16   0.24824E-16   0.34841E-16   0.46450E-16
  15     0.33402E-17   0.55325E-17   0.81501E-17   0.11180E-16   0.16484E-16   0.24957E-16   0.35016E-16   0.46671E-16
  16     0.33664E-17   0.55715E-17   0.82029E-17   0.11247E-16   0.16575E-16   0.25083E-16   0.35016E-16   0.46671E-16
  17     0.33913E-17   0.56086E-17   0.82530E-17   0.11312E-16   0.16662E-16   0.25203E-16   0.35016E-16   0.46671E-16
  18     0.34150E-17   0.56440E-17   0.83009E-17   0.11373E-16   0.16745E-16   0.25203E-16   0.35016E-16   0.46671E-16
  19     0.34377E-17   0.56778E-17   0.83466E-17   0.11431E-16   0.16745E-16   0.25203E-16   0.35016E-16   0.46671E-16
  20     0.34594E-17   0.57101E-17   0.83904E-17   0.11487E-16   0.16745E-16   0.25203E-16   0.35016E-16   0.46671E-16
  21     0.34802E-17   0.57412E-17   0.84325E-17   0.11487E-16   0.16745E-16   0.25203E-16   0.35016E-16   0.46671E-16
  22     0.35002E-17   0.57710E-17   0.84325E-17   0.11487E-16   0.16745E-16   0.25203E-16   0.35016E-16   0.46671E-16
  23     0.35195E-17   0.57996E-17   0.84325E-17   0.11487E-16   0.16745E-16   0.25203E-16   0.35016E-16   0.46671E-16
  24     0.35380E-17   0.57996E-17   0.84325E-17   0.11487E-16   0.16745E-16   0.25203E-16   0.35016E-16   0.46671E-16

          0.1600E-05    0.2000E-05    0.2600E-05    0.3500E-05    0.5000E-05    0.8000E-05    0.1500E-04
   1     0.38675E-16   0.57246E-16   0.91469E-16   0.15693E-15   0.30391E-15   0.73569E-15   0.24038E-14
   2     0.49418E-16   0.73240E-16   0.11718E-15   0.20155E-15   0.39134E-15   0.94250E-15   0.30481E-14
   3     0.54462E-16   0.80878E-16   0.12962E-15   0.22342E-15   0.43298E-15   0.10417E-14   0.33561E-14
   4     0.57399E-16   0.85518E-16   0.13777E-15   0.23818E-15   0.46311E-15   0.11099E-14   0.35672E-14
   5     0.59432E-16   0.88652E-16   0.14310E-15   0.24886E-15   0.48530E-15   0.11673E-14   0.37197E-14
   6     0.60977E-16   0.90996E-16   0.14702E-15   0.25603E-15   0.50292E-15   0.12138E-14   0.38398E-14
   7     0.62218E-16   0.92857E-16   0.15009E-15   0.26158E-15   0.51482E-15   0.12517E-14   0.39484E-14
   8     0.63252E-16   0.94396E-16   0.15260E-15   0.26604E-15   0.52416E-15   0.12842E-14   0.40560E-14
   9     0.64137E-16   0.95703E-16   0.15471E-15   0.26975E-15   0.53173E-15   0.13072E-14   0.41625E-14
  10     0.64909E-16   0.96837E-16   0.15653E-15   0.27291E-15   0.53801E-15   0.13252E-14   0.42512E-14
  11     0.65593E-16   0.97837E-16   0.15813E-15   0.27564E-15   0.54336E-15   0.13397E-14   0.43261E-14
  12     0.66207E-16   0.98730E-16   0.15954E-15   0.27804E-15   0.54798E-15   0.13517E-14   0.43947E-14
  13     0.66540E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.44345E-14
  14     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.44670E-14
  15     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.44942E-14
  16     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45174E-14
  17     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45376E-14
  18     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45376E-14
  19     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45376E-14
  20     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45376E-14
  21     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45376E-14
  22     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45376E-14
  23     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45376E-14
  24     0.66855E-16   0.99200E-16   0.16025E-15   0.27919E-15   0.54998E-15   0.13562E-14   0.45376E-14
```

```
PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  1 OF CORRECTION PARAMETERS
   SIZE      CCF   INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.  COR. W    COR. P
 2.500E-07  1.589   0.008   0.0201      0.0235      59.1650      5.563   40.8350   44.1728    3.621    55.8272
 3.500E-07  1.414   0.049   0.1299      0.1259      58.7095      5.494   41.2905   53.2243    4.720    46.7757
 4.500E-07  1.320   0.212   0.5586      0.5037      59.1955      5.568   40.8045   56.9958    5.242    43.0042
 5.500E-07  1.261   0.597   1.5720      1.3489      60.2813      5.736   39.7187   59.1249    5.557    40.8751
 7.000E-07  1.205   2.119   5.2257      4.5857      61.8360      5.984   38.1640   60.8553    5.826    39.1447
 9.000E-07  1.159   2.985   6.8981      6.0652      64.2328      6.386   35.7672   63.2414    6.217    36.7586
 1.100E-06  1.130   3.582   7.7967      6.8762      66.3110      6.758   33.6890   65.2722    6.570    34.7278
 1.300E-06  1.110   3.283   6.7014      5.9733      68.4115      7.158   31.5885   67.0893    6.903    32.9107
 1.600E-06  1.090   6.865  12.8769     11.5702      70.9701      7.683   29.0299   69.5117    7.378    30.4883
 2.000E-06  1.072   7.164  12.0580     10.9277      73.9489      8.355   26.0511   72.4045    7.998    27.5955
 2.600E-06  1.055  11.940  17.1710     15.9605      77.7415      9.333   22.2585   75.8173    8.818    24.1827
 3.500E-06  1.041  10.447  12.2611     11.9976      81.8356     10.595   18.1644   79.2248    9.761    20.7752
 5.000E-06  1.029  14.925  12.0579     12.7853      87.4957     12.915   12.5043   84.5027   11.582    15.4973
 8.000E-06  1.018  14.925   4.1302      6.5873      95.7169     19.570    4.2831   92.0154   15.701     7.9846
 1.500E-05  1.010  20.899   0.5822      4.6689      99.5688     33.831    0.4312   95.9584   19.930     4.0816
   EFFICIENCY - STATED = 99.00      COMPUTED = 79.0054      CONVERGENCE OBTAINED

   ADJUSTED NO-RAP EFF. =  84.5225
   MMD OF INLET SIZE DISTRIBUTION =  3.987E+00
   SIGMAP OF INLET SIZE DISTRIBUTION =  2.165E+00
   LOG-NORMAL GOODNESS OF FIT =  0.985
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.083E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.804E+00
   LOG-NORMAL GOODNESS OF FIT =  0.996
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 11.590

   SIGMAG=    0.000  WITH  0.000 SNEAKAGE OVER    4.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  81.9092
   CORRECTED MMD OF EFFLUENT =  2.485E+00
   CORRECTED SIGMAP OF EFFLUENT =  1.962E+00
   LOG-NORMAL GOODNESS OF FIT =  0.991
   CORRECTED PRECIPITATION RATE PARAMETER =   10.62
```

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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP            RAPPING PUFF       NO-RAP+RAP PUFF      RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)   EFFICIENCY(%)    DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 2.393E+00           3.197E+01          2.862E-02          1.051E-02          3.912E-02          4.360E-02        2.500E-07
 2.532E+00           3.348E+01          2.613E-01          3.472E-02          2.960E-01          1.022E-01        3.500E-07
 2.716E+00           3.542E+01          1.449E+00          7.809E-02          1.527E+00          1.784E-01        4.500E-07
 2.919E+00           3.749E+01          4.862E+00          1.416E-01          5.004E+00          2.642E-01        5.500E-07
 3.234E+00           4.059E+01          1.051E+01          2.701E-01          1.078E+01          7.953E-01        7.000E-07
 3.670E+00           4.462E+01          1.789E+01          4.959E-01          1.838E+01          1.132E+00        9.000E-07
 4.101E+00           4.832E+01          2.474E+01          7.630E-01          2.551E+01          1.424E+00        1.100E-06
 4.548E+00           5.191E+01          2.516E+01          1.053E+00          2.621E+01          1.661E+00        1.300E-06
 5.212E+00           5.679E+01          2.965E+01          1.489E+00          3.114E+01          3.831E+00        1.600E-06
 6.099E+00           6.254E+01          3.477E+01          2.061E+00          3.683E+01          4.234E+00        2.000E-06
 7.454E+00           6.988E+01          3.203E+01          2.769E+00          3.480E+01          8.791E+00        2.600E-06
 9.502E+00           7.834E+01          2.466E+01          3.545E+00          2.821E+01          1.044E+01        3.500E-06
 1.291E+01           8.750E+01          1.721E+01          4.119E+00          2.133E+01          1.709E+01        5.000E-06
 1.957E+01           9.572E+01          4.678E+00          4.043E+00          8.722E+00          2.114E+01        8.000E-06
 3.383E+01           9.957E+01          4.861E-01          4.070E+00          4.556E+00          2.887E+01        1.500E-05
```

```
*****************************************************************************************
*                                                                                       *
*                          SUMMARY TABLE OF ESP OPERATING                               *
*                            PARAMETERS AND PERFORMANCE                                 *
*                                                                                       *
*                                                                                       *
*                              DATA SET NUMBER    1                                     *
*                                                                                       *
*  ESP PERFORMANCE:     EFFICIENCY =  81.9092 %     SCA =  1.610E+01 M**2/(M**3/SEC)    *
*                                                                                       *
*  ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.020E+04 V                       *
*                             AVG. CURRENT DENSITY =   10.11 NA/CM**2                   *
*                             RESISTIVITY =  1.000E+09 OHM-CM                           *
*                                                                                       *
*  SIZE DISTRIBUTIONS:     INLET MMD =  3.987E+00 UM     INLET SIGMAP =  2.165E+00      *
*                          OUTLET MMD =  2.485E+00 UM     OUTLET SIGMAP =  1.962E+00    *
*                                                                                       *
*  NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.00 /SECTION     GAS VELOCITY SIGMAG = 0.00 *
*                           RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00 *
*                                                                                       *
*****************************************************************************************
```

```
PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  2 OF CORRECTION PARAMETERS

   SIZE       CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W     COR. P
 2.500E-07  1.589  0.008    0.0179        0.0210      54.9130     4.948   45.0870   39.4952    3.121     60.5048
 3.500E-07  1.414  0.049    0.1157        0.1141      54.4426     4.884   45.5574   48.8017    4.158     51.1983
 4.500E-07  1.320  0.212    0.4986        0.4593      54.8886     4.945   45.1114   52.6265    4.641     47.3735
 5.500E-07  1.261  0.597    1.3727        1.2364      55.9224     5.089   44.0776   54.7332    4.923     45.2668
 7.000E-07  1.205  2.119    4.7090        4.2278      57.4040     5.301   42.5960   56.3954    5.156     43.6046
 9.000E-07  1.159  2.985    6.2735        5.6414      59.7104     5.647   40.2896   58.6907    5.492     41.3093
 1.100E-06  1.130  3.582    7.1533        6.4488      61.7165     5.964   38.2835   60.6482    5.793     39.3518
 1.300E-06  1.110  3.283    6.2075        5.6485      63.7581     6.305   36.2419   62.3985    6.076     37.6015
 1.600E-06  1.090  6.865   12.0867       11.0716      66.2502     6.747   33.7498   64.7504    6.477     35.2496
 2.000E-06  1.072  7.164   11.5199       10.6240      69.1731     7.310   30.8269   67.5849    6.998     32.4151
 2.600E-06  1.055 11.940   16.8568       15.8651      72.9351     8.118   27.0649   70.9563    7.680     29.0437
 3.500E-06  1.041 10.447   12.5155       12.2600      77.0347     9.138   22.9653   74.3497    8.452     25.6503
 5.000E-06  1.029 14.925   13.2853       13.7535      82.9356    10.983   17.0644   79.8576    9.953     20.1424
 8.000E-06  1.018 14.925    5.7558        7.6473      92.6069    16.179    7.3931   88.8003   13.599     11.1997
 1.500E-05  1.010 20.899    1.6318        4.9811      98.5031    26.100    1.4969   94.7902   18.353      5.2098

    EFFICIENCY - STATED = 99.00     COMPUTED = 79.0054     CONVERGENCE OBTAINED


    ADJUSTED NO-RAP EFF. =  80.8296
    MMD OF INLET SIZE DISTRIBUTION =  3.987E+00
    SIGMAP OF INLET SIZE DISTRIBUTION =  2.165E+00
    LOG-NORMAL GOODNESS OF FIT =  0.985
    MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.292E+00
    SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.871E+00
    LOG-NORMAL GOODNESS OF FIT =  0.995
    PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 10.260


    SIGMAG=    0.100  WITH  0.100 SNEAKAGE OVER    4.000  STAGES
    NTEMP = 1
    RMMD =  6.00
    RSIGMA = 2.50
    CORR. EFF. =  78.1421
    CORRECTED MMD OF EFFLUENT =  2.579E+00
    CORRECTED SIGMAP OF EFFLUENT =  1.971E+00
    LOG-NORMAL GOODNESS OF FIT =  0.991
    CORRECTED PRECIPITATION RATE PARAMETER =    9.45
```

```
UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED       NO-RAP              RAPPING PUFF        NO-RAP+RAP PUFF      RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)    EFFICIENCY(%)     DM/DLOGD(MG/DSCM)   DM/DLOGD(MG/DSCM)   DM/DLOGD(MG/DSCM)   DISTRIBUTION(%)   DIAM.(M)
  2.393E+00            3.197E+01           3.159E-02           1.080E-02           4.240E-02           4.360E-02         2.500E-07
  2.532E+00            3.348E+01           2.883E-01           3.570E-02           3.240E-01           1.022E-01         3.500E-07
  2.716E+00            3.542E+01           1.602E+00           8.031E-02           1.682E+00           1.780E-01         4.500E-07
  2.919E+00            3.749E+01           5.396E+00           1.456E-01           5.541E+00           2.642E-01         5.500E-07
  3.234E+00            4.059E+01           1.173E+01           2.778E-01           1.201E+01           7.953E-01         7.000E-07
  3.670E+00            4.462E+01           2.015E+01           5.099E-01           2.066E+01           1.132E+00         9.000E-07
  4.101E+00            4.832E+01           2.812E+01           7.847E-01           2.890E+01           1.424E+00         1.100E-06
  4.548E+00            5.191E+01           2.886E+01           1.083E+00           2.994E+01           1.661E+00         1.300E-06
  5.212E+00            5.679E+01           3.447E+01           1.532E+00           3.600E+01           3.831E+00         1.600E-06
  6.099E+00            6.254E+01           4.114E+01           2.120E+00           4.326E+01           4.234E+00         2.000E-06
  7.454E+00            6.988E+01           3.895E+01           2.848E+00           4.180E+01           8.791E+00         2.600E-06
  9.502E+00            7.834E+01           3.118E+01           3.645E+00           3.483E+01           1.044E+01         3.500E-06
  1.291E+01            8.750E+01           2.348E+01           4.236E+00           2.772E+01           1.709E+01         5.000E-06
  1.957E+01            9.572E+01           8.076E+00           4.158E+00           1.223E+01           2.114E+01         8.000E-06
  3.383E+01            9.957E+01           1.687E+00           4.185E+00           5.872E+00           2.887E+01         1.500E-05
```

```
*****************************************************************************************
*                                                                                       *
*                            SUMMARY TABLE OF ESP OPERATING                             *
*                             PARAMETERS AND PERFORMANCE                                *
*                                                                                       *
*                                                                                       *
*                                  DATA SET NUMBER   2                                  *
*                                                                                       *
*         ESP PERFORMANCE:     EFFICIENCY =  78.1421 %     SCA =  1.610E+01 M**2/(M**3/SEC)
*                                                                                       *
*         ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.020E+04 V                *
*                                                                                       *
*                                    AVG. CURRENT DENSITY =   10.11 NA/CM**2            *
*                                                                                       *
*                                    RESISTIVITY =  1.000E+09 OHM-CM                    *
*                                                                                       *
*         SIZE DISTRIBUTIONS:     INLET MMD =  3.987E+00 UM     INLET SIGMAP =  2.165E+00
*                                                                                       *
*                                 OUTLET MMD =  2.579E+00 UM     OUTLET SIGMAP =  1.971E+00
*                                                                                       *
*         NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.10 /SECTION     GAS VELOCITY SIGMAG = 0.10
*                                                                                       *
*                                  RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00
*                                                                                       *
*****************************************************************************************
STOP  011111
```

APPENDIX J

OUTPUT DATA FOR EXAMPLE 2 (REVISION 1)

```
                    ***************************************
                    *                                     *
                    *          E.P.A. ESP MODEL           *
                    *                                     *
                    *   I.E.R.L.-R.T.P. AND SO.R.I.       *
                    *                                     *
                    *      REVISION I,JAN. 1, 1978        *
                    *                                     *
                    ***************************************

PRINTOUT OF INPUT DATA FOR DATA SET NUMBER  1


DATA ON CARD NUMBER   1

NENDPT = 16   NDATA =  1

DATA ON CARD NUMBER   2

LAB ESP; SCA=82FT2/1000ACFM;CALCULATED V-I FOR EACH ELECTRICAL SECTION

DATA ON CARD NUMBER   3

NEST =  1  NDIST =  1  NVI =  2  NX = 15  NY = 15  NITER =  1  NCALC =  0  NRAPD =  1  NEFF =  1  NTEMP =  1  NONID =  2

DATA ON CARD NUMBER   4

NN = 10  NUMINC = 20

DATA ON CARD NUMBER   5

IFINAL = 20  JI1 =  2  JI2 = 21  VISKIP = 1  VISAME =  2

DATA ON CARD NUMBER   6

DL =  0.06500 GRN/ACF  PL =  10.0000 FT  ETAO = 99.00000 %  DD =  1000.00 KG/M**3  EPS =  5.100E+00
VRATIO =   1.0300  US = 0.000165 M**2/V-SEC  FPATH =   1.0000  EBD = 1500000. V/M  RHOCGS =  1.00E+09 OHM-CM

DATA ON CARD NUMBER   7

ASNUCK( 1) = 0.00  AZIGGY( 1) = 0.00  AZNUMS( 1) =  4.0
```

```
ABNUCK( 2) = 0.10  AZIGGY( 2) = 0.10  AZNUMS( 2) =  4.0


DATA ON CARD NUMBER   8

ENDPT( 1) =    0.200 UM   ENDPT( 2) =    0.300 UM   ENDPT( 3) =    0.400 UM   ENDPT( 4) =    0.500 UM   ENDPT( 5) =    0.600 UM
ENDPT( 6) =    0.800 UM   ENDPT( 7) =    1.000 UM   ENDPT( 8) =    1.200 UM   ENDPT( 9) =    1.400 UM   ENDPT(10) =    1.800 UM


DATA ON CARD NUMBER   9

ENDPT(11) =    2.200 UM   ENDPT(12) =    3.000 UM   ENDPT(13) =    4.000 UM   ENDPT(14) =    6.000 UM   ENDPT(15) =   10.000 UM
ENDPT(16) =   20.000 UM

DATA ON CARD NUMBER  10

PRCU( 1) =   0.0000 %   PRCU( 2) =   0.0076 %   PRCU( 3) =   0.0563 %   PRCU( 4) =   0.2682 %   PRCU( 5) =   0.8652 %
PRCU( 6) =   2.9845 %   PRCU( 7) =   5.9695 %   PRCU( 8) =   9.5515 %   PRCU( 9) =  12.8350 %   PRCU(10) =  19.7004 %


DATA ON CARD NUMBER  11

PRCU(11) =  26.8643 %   PRCU(12) =  38.8042 %   PRCU(13) =  49.2516 %   PRCU(14) =  64.1765 %   PRCU(15) =  79.1014 %
PRCU(16) = 100.0000 %

DATA ON CARD NUMBER  12

NUMSEC =  3    LSECT( 1) =  6  LSECT( 2) =  6  LSECT( 3) = 12

DATA ON CARD NUMBER  13

AS( 1) =  6.2500E+00 FT**2  VOS( 1) =  4.0800E+04 V  TCS( 1) =  6.2500E-05 A  WLS( 1) =  6.2500E+00 FT
ACS( 1) =  4.6875E-02 IN  DS( 1) =  5.0000E+00 IN  NWS( 1) =  5.0000E+00

DATA ON CARD NUMBER  14

SVS( 1) =  2.5000E+00 IN  VOS( 1) =  3.0533E+02 FT**3/MIN  VGASS( 1) =  4.8853E+00 FT/SEC  TEMPS( 1) =  7.6000E+01 F
PS( 1) =  1.0000E+00 ATM  VISS( 1) =  1.8000E-05 KG/M-SEC  LINCS( 1) =  4.1667E-01 FT
```

```
DATA ON CARD NUMBER  15

RFS( 1) =  9.0000E-01  START1( 1) =  6.0000E-05 A/M**2  START2( 1) =  2.0000E-05 A/M**2
STARTS( 1) =  2.0000E-05 A/M**2  VSTAR( 1) =  3.8000E+04 V

DATA ON CARD NUMBER  16

AS( 2) =  6.2500E+00 FT**2  VOS( 2) =  4.0800E+04 V  TCS( 2) =  6.2500E-05 A  WLS( 2) =  6.2500E+00 FT
ACS( 2) =  4.6875E-02 IN  BS( 2) =  5.0000E+00 IN  NWS( 2) =  5.0000E+00

DATA ON CARD NUMBER  17

SVS( 2) =  2.5000E+00 IN  VGS( 2) =  3.0533E+02 FT**3/MIN  VGASS( 2) =  4.8853E+00 FT/SEC  TEMPS( 2) =  7.6000E+01 F
PS( 2) =  1.0000E+00 ATM  VISS( 2) =  1.8000E-05 KG/M-SEC  LINCS( 2) =  4.1667E-01 FT

DATA ON CARD NUMBER  18

RFS( 2) =  9.0000E-01  START1( 2) =  6.0000E-05 A/M**2  START2( 2) =  2.0000E-05 A/M**2
START3( 2) =  2.0000E-05 A/M**2  VSTAR( 2) =  3.8000E+04 V

DATA ON CARD NUMBER  19

AS( 3) =  1.2500E+01 FT**2  VOS( 3) =  3.9600E+04 V  TCS( 3) =  1.2500E-04 A  WLS( 3) =  1.2500E+01 FT
ACS( 3) =  4.6875E-02 IN  BS( 3) =  5.0000E+00 IN  NWS( 3) =  1.0000E+01

DATA ON CARD NUMBER  20

SVS( 3) =  2.5000E+00 IN  VGS( 3) =  3.0533E+02 FT**3/MIN  VGASS( 3) =  4.8853E+00 FT/SEC  TEMPS( 3) =  7.6000E+01 F
PS( 3) =  1.0000E+00 ATM  VISS( 3) =  1.8000E-05 KG/M-SEC  LINCS( 3) =  4.1667E-01 FT

DATA ON CARD NUMBER  21

RFS( 3) =  9.0000E-01  START1( 3) =  6.0000E-05 A/M**2  START2( 3) =  2.0000E-05 A/M**2
START3( 3) =  2.0000E-05 A/M**2  VSTAR( 3) =  3.8000E+04 V
```

```
CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  1

                 VW = -3.8000E+04  ACDNTY =  6.0276E-05  AEPLT = -1.7902E+05

                 VW = -3.8206E+04  ACDNTY =  7.9337E-05  AEPLT = -1.8897E+05

                 VW = -3.8896E+04  ACDNTY =  9.9193E-05  AEPLT = -1.9435E+05

                 VW = -3.9513E+04  ACDNTY =  1.1904E-04  AEPLT = -2.0232E+05

                 VW = -4.0098E+04  ACDNTY =  1.3890E-04  AEPLT = -2.0993E+05

                 VW = -4.0656E+04  ACDNTY =  1.5874E-04  AEPLT = -2.1722E+05

                 VW = -4.1193E+04  ACDNTY =  1.7859E-04  AEPLT = -2.2424E+05

                 VW = -4.0711E+04  ACDNTY =  1.6851E-04  AEPLT = -2.1842E+05


INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


LAB ESP: SCA=82FT2/1000ACFM;CALCULATED V-I FOR EACH ELECTRICAL SECTION

CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2       APPLIED VOLTAGE =  4.080E+04 VOLTS        TOTAL CURRENT =  9.446E-05 AMPS
WIRE TO PLATE =  1.270E-01 M          CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  4.955E-05 AMP/M          CURRENT DENSITY =  1.625E-04 AMP/M2       DEPOSIT E FIELD =  1.625E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M       GAS FLOW RATE =  1.444E-01 M3/SEC         GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K               PRESSURE =  1.000 ATM                     VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC MEAN THERMAL SPEED =  4.436E+02 M/SEC     PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC       LENGTH INCR. =0.12708435 M                INPUT EFF./INCR. = 17.46

RIOVR     ERAVG      EPLT        AFID        CMCD     MMD        WEIGHT      DUST LAYER   J(PART)     J(ION)    INCR. NO.

0.8267   2,085E+05  2.1842E+05  2.1564E+13   13.4   7.30E-06   6.220E-06   5.570E-04   3.88E-08   1.62E-04      1
0.7338   2,085E+05  2.1842E+05  2.1580E+13   11.9   4.34E-06   9.904F-06   8.859E-04   9.22E-08   1.62E-04      2
0.7114   2,085E+05  2.1842E+05  2.1582E+13   11.6   2.92E-06   1.026E-05   9.180E-04   1.14E-07   1.62E-04      3
0.7040   2.085E+05  2.1842E+05  2.1582E+13   11.4   2.26E-06   9.832E-06   8.794E-04   1.28E-07   1.62E-04      4
0.7027   2.085E+05  2.1842E+05  2.1583E+13   11.4   1.90E-06   9.138E-06   8.174E-04   1.33E-07   1.62E-04      5
0.7047   2.085E+05  2.1842E+05  2.1583E+13   11.5   1.62E-06   8.361E-06   7.479E-04   1.34E-07   1.62E-04      6
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                    CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  2

                              VW = -3.8000E+04  ACDNTY =  6.0276E-05  AEPLT = -1.7902E+05

                              VW = -3.8206E+04  ACDNTY =  7.9337E-05  AEPLT = -1.8597E+05

                              VW = -3.8896E+04  ACDNTY =  9.9193E-05  AEPLT = -1.9435E+05

                              VW = -3.9513E+04  ACDNTY =  1.1904E-04  AEPLT = -2.0232E+05

                              VW = -4.0098E+04  ACDNTY =  1.3890E-04  AEPLT = -2.0993E+05

                              VW = -4.0656E+04  ACDNTY =  1.5874E-04  AEPLT = -2.1722E+05

                              VW = -4.1193E+04  ACDNTY =  1.7859E-04  AEPLT = -2.2424E+05

                              VW = -4.0711E+04  ACDNTY =  1.6251E-04  AEPLT = -2.1842E+05

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2         APPLIED VOLTAGE =  4.080E+04 VOLTS        TOTAL CURRENT =  9.446E-05 AMPS
WIRE TO PLATE =  1.270E-01 M            CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  4.955E-05 AMP/M            CURRENT DENSITY =  1.625E-04 AMP/M2       DEPOSIT E FIELD =  1.628E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M         GAS FLOW RATE =  1.444E-01 M3/SEC         GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                 PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  4.436E+02 M/SEC     PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC         LENGTH INCR. =0.12708435 M                INPUT EFF./INCR. = 17.46

RIOVR     ERAVG        EPLT        AFID         CMCD      MMD         WEIGHT      DUST LAYER   J(PART)       J(ION)    INCR. NO.

0.7085   2.085E+05  2.1842E+05  2.1583E+13     11.5   1.44E-06    7.585E-06   6.784E-04   1.32E-07     1.62E-04        7
0.7134   2.085E+05  2.1842E+05  2.1583E+13     11.6   1.32E-06    6.849E-06   6.126E-04   1.29E-07     1.62E-04        8
0.7190   2.085E+05  2.1842E+05  2.1583E+13     11.7   1.18E-06    6.170E-06   5.519E-04   1.25E-07     1.62E-04        9
0.7250   2.085E+05  2.1842E+05  2.1583E+13     11.8   1.07E-06    5.556E-06   4.970E-04   1.21E-07     1.62E-04       10
0.7313   2.085E+05  2.1842E+05  2.1583E+13     11.9   9.89E-07    5.006E-06   4.478E-04   1.16E-07     1.62E-04       11
0.7377   2.085E+05  2.1842E+05  2.1583E+13     12.0   9.25E-07    4.517E-06   4.040E-04   1.12E-07     1.62E-04       12

                    CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  3

                              VW = -3.8000E+04  ACDNTY =  6.0277E-05  AEPLT = -1.7902E+05

                              VW = -3.8205E+04  ACDNTY =  7.9332E-05  AEPLT = -1.8596E+05

                              VW = -3.8896E+04  ACDNTY =  9.9192E-05  AEPLT = -1.9435E+05
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                  VW = -3.9512E+04  ACDNTY =  1.1904E-04  AEPLT = -2.0232E+05

                  VW = -4.0098E+04  ACDNTY =  1.3889E-04  AEPLT = -2.0993E+05

                  VW = -3.9514E+04  ACDNTY =  1.2081E-04  AEPLT = -2.0279E+05


CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  1.5250 M

COLLECTION AREA =  1.162E+00 M2        APPLIED VOLTAGE =  3.960E+04 VOLTS        TOTAL CURRENT =  1.404E-04 AMPS
WIRE TO PLATE =  1.270E-01 M           CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  3.812E+00 M
CURRENT/M =  3.684E-05 AMP/M           CURRENT DENSITY =  1.208E-04 AMP/M2       DEPOSIT E FIELD =  1.208E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M        GAS FLOW RATE =  1.444E-01 M3/SEC         GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.436E+02 M/SEC     PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC        LENGTH INCR. =0.12708435 M                INPUT EFF./INCR. = 17.46

RIOVR    ERAVG       EPLT         AFID        CMCD    MMD       WEIGHT     DUST LAYER  J(PART)      J(ION)    INCR. NO.

0.6987   2.001E+05  2.0279E+05  1.7774E+13    8.4   8.44E-07   3.800E-06   3.399E-04   9.93E-08    1.21E-04      13
0.7020   2.001E+05  2.0279E+05  1.7774E+13    8.5   7.96E-07   3.456E-06   3.091E-04   9.48E-08    1.21E-04      14
0.7094   2.001E+05  2.0279E+05  1.7774E+13    8.6   7.57E-07   3.150E-06   2.818E-04   9.04E-08    1.21E-04      15
0.7167   2.001E+05  2.0279E+05  1.7774E+13    8.7   7.25E-07   2.881E-06   2.577E-04   8.62E-08    1.21E-04      16
0.7240   2.001E+05  2.0279E+05  1.7774E+13    8.8   6.99E-07   2.644E-06   2.365E-04   8.22E-08    1.21E-04      17
0.7312   2.001E+05  2.0279E+05  1.7774E+13    8.8   6.73E-07   2.433E-06   2.176E-04   7.85E-08    1.21E-04      18
0.7382   2.001E+05  2.0279E+05  1.7774E+13    8.9   6.52E-07   2.246E-06   2.009E-04   7.49E-08    1.21E-04      19
0.7451   2.001E+05  2.0279E+05  1.7774E+13    9.0   6.34E-07   2.079E-06   1.859E-04   7.15E-08    1.21E-04      20
0.7520   2.001E+05  2.0279E+05  1.7774E+13    9.1   6.18E-07   1.929E-06   1.725E-04   6.84E-08    1.21E-04      21
0.7587   2.001E+05  2.0279E+05  1.7774E+13    9.2   6.05E-07   1.794E-06   1.605E-04   6.53E-08    1.21E-04      22
0.7652   2.001E+05  2.0279E+05  1.7774E+13    9.2   5.94E-07   1.672E-06   1.496E-04   6.25E-08    1.21E-04      23
0.7716   2.001E+05  2.0279E+05  1.7774E+13    9.3   5.84E-07   1.562E-06   1.397E-04   5.98E-08    1.21E-04      24

DESIGN EFFICIENCY = 99.00      UNCORRECTED COMPUTED EFFICIENCY = 79.98
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CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHARGN OR CHGSUM

SRI THEORY USED FOR PARTICLE CHARGING

INCREMENT NO.     Q/QSATF FOR INDICATED PARTICLE SIZES

   0.2500E-06   0.3500E-06   0.4500E-06   0.5500E-06   0.7000E-06   0.9000E-06   0.1100E-05   0.1300E-05
 1  1.0603       1.0325       0.9918       0.9523       0.9013       0.8506       0.8118       0.7815
 2  1.3302       1.2853       1.2346       1.1900       1.1363       1.0790       1.0324       0.9955
 3  1.4762       1.4174       1.3567       1.3049       1.2438       1.1825       1.1364       1.1015
 4  1.5763       1.5066       1.4380       1.3803       1.3130       1.2472       1.1991       1.1633
 5  1.6522       1.5738       1.4987       1.4362       1.3638       1.2940       1.2436       1.2064
 6  1.7134       1.6276       1.5470       1.4805       1.4038       1.3308       1.2779       1.2392
 7  1.7645       1.6723       1.5871       1.5172       1.4368       1.3602       1.3057       1.2656
 8  1.8083       1.7107       1.6214       1.5484       1.4647       1.3853       1.3290       1.2876
 9  1.8467       1.7441       1.6512       1.5755       1.4889       1.4070       1.3491       1.3064
10  1.8809       1.7738       1.6776       1.5995       1.5103       1.4261       1.3666       1.3229
11  1.9116       1.8005       1.7013       1.6210       1.5294       1.4431       1.3822       1.3374
12  1.9395       1.8248       1.7228       1.6405       1.5467       1.4584       1.3963       1.3505
13  1.9579       1.8403       1.7364       1.6526       1.5571       1.4675       1.4043       1.3578
14  1.9752       1.8550       1.7492       1.6639       1.5670       1.4760       1.4120       1.3647
15  1.9916       1.8689       1.7612       1.6747       1.5763       1.4841       1.4192       1.3713
16  2.0072       1.8821       1.7727       1.6849       1.5852       1.4918       1.4260       1.3713
17  2.0219       1.8946       1.7836       1.6946       1.5937       1.4990       1.4260       1.3713
18  2.0360       1.9066       1.7940       1.7039       1.6017       1.4990       1.4260       1.3713
19  2.0495       1.9180       1.8040       1.7128       1.6094       1.4990       1.4260       1.3713
20  2.0624       1.9289       1.8135       1.7213       1.6094       1.4990       1.4260       1.3713
21  2.0747       1.9394       1.8226       1.7213       1.6094       1.4990       1.4260       1.3713
22  2.0866       1.9495       1.8314       1.7213       1.6094       1.4990       1.4260       1.3713
23  2.0980       1.9592       1.8314       1.7213       1.6094       1.4990       1.4260       1.3713
24  2.1089       1.9592       1.8314       1.7213       1.6094       1.4990       1.4260       1.3713

   0.1600E-05   0.2000E-05   0.2600E-05   0.3500E-05   0.5000E-05   0.8000E-05   0.1500E-04
 1  0.7479       0.7141       0.6800       0.6459       0.6124       0.5762       0.5399
 2  0.9532       0.9108       0.8690       0.8260       0.7808       0.7332       0.6825
 3  1.0611       1.0142       0.9651       0.9159       0.8656       0.8132       0.7558
 4  1.1232       1.0811       1.0352       0.9818       0.9242       0.8678       0.8062
 5  1.1653       1.1241       1.0814       1.0335       0.9730       0.9088       0.8449
 6  1.1967       1.1553       1.1133       1.0698       1.0141       0.9440       0.8749
 7  1.2217       1.1795       1.1373       1.0949       1.0461       0.9766       0.8999
 8  1.2423       1.1992       1.1564       1.1143       1.0686       1.0048       0.9224
 9  1.2598       1.2158       1.1721       1.1298       1.0855       1.0280       0.9434
10  1.2750       1.2300       1.1855       1.1427       1.0988       1.0461       0.9633
11  1.2885       1.2425       1.1971       1.1537       1.1098       1.0596       0.9822
12  1.3004       1.2536       1.2073       1.1632       1.1191       1.0702       0.9983
13  1.3070       1.2594       1.2123       1.1676       1.1230       1.0740       1.0064
14  1.3132       1.2594       1.2123       1.1676       1.1230       1.0740       1.0130
15  1.3132       1.2594       1.2123       1.1676       1.1230       1.0740       1.0185
16  1.3132       1.2594       1.2123       1.1676       1.1230       1.0740       1.0233
17  1.3132       1.2594       1.2123       1.1676       1.1230       1.0740       1.0233
18  1.3132       1.2594       1.2123       1.1676       1.1230       1.0740       1.0233
19  1.3132       1.2594       1.2123       1.1676       1.1230       1.0740       1.0233
20  1.3132       1.2594       1.2123       1.1676       1.1230       1.0740       1.0233
21  1.3132       1.2594       1.2123       1.1676       1.1230       1.0740       1.0233
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22	1.3132	1.2594	1.2123	1.1676	1.1230	1.0740	1.0233
23	1.3132	1.2594	1.2123	1.1676	1.1230	1.0740	1.0233
24	1.3132	1.2594	1.2123	1.1676	1.1230	1.0740	1.0233

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 CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT

INCREMENT        CHARGE FOR INDICATED PARTICLE SIZES

       0.2500E-06    0.3500E-06    0.4500E-06    0.5500E-06    0.7000E-06    0.9000E-06    0.1100E-05    0.1300E-05
  1   0.18113E-17   0.31194E-17   0.46963E-17   0.65249E-17   0.97189E-17   0.14033E-16   0.20870E-16   0.27819E-16
  2   0.22722E-17   0.38832E-17   0.58463E-17   0.81534E-17   0.12252E-16   0.18815E-16   0.26541E-16   0.35435E-16
  3   0.25218E-17   0.42824E-17   0.64245E-17   0.89407E-17   0.13411E-16   0.20620E-16   0.29214E-16   0.39209E-16
  4   0.26927E-17   0.45519E-17   0.68092E-17   0.94575E-17   0.14158E-16   0.21749E-16   0.30828E-16   0.41410E-16
  5   0.28224E-17   0.47548E-17   0.70966E-17   0.98407E-17   0.14706E-16   0.22564E-16   0.31972E-16   0.42944E-16
  6   0.29268E-17   0.49173E-17   0.73255E-17   0.10144E-16   0.15137E-16   0.23199E-16   0.32853E-16   0.44111E-16
  7   0.30141E-17   0.50525E-17   0.75154E-17   0.10395E-16   0.15492E-16   0.23718E-16   0.33568E-16   0.45051E-16
  8   0.30891E-17   0.51683E-17   0.76776E-17   0.10609E-16   0.15793E-16   0.24156E-16   0.34167E-16   0.45833E-16
  9   0.31547E-17   0.52695E-17   0.78189E-17   0.10795E-16   0.16055E-16   0.24535E-16   0.34683E-16   0.46504E-16
 10   0.32130E-17   0.53593E-17   0.79440E-17   0.10960E-16   0.16285E-16   0.24867E-16   0.35134E-16   0.47088E-16
 11   0.32655E-17   0.54399E-17   0.80563E-17   0.11107E-16   0.16491E-16   0.25164E-16   0.35535E-16   0.47606E-16
 12   0.33132E-17   0.55131E-17   0.81581E-17   0.11240E-16   0.16678E-16   0.25431E-16   0.35896E-16   0.48071E-16
 13   0.33446E-17   0.55601E-17   0.82222E-17   0.11323E-16   0.16790E-16   0.25589E-16   0.36103E-16   0.48333E-16
 14   0.33742E-17   0.56045E-17   0.82827E-17   0.11401E-16   0.16897E-16   0.25738E-16   0.36290E-16   0.48579E-16
 15   0.34022E-17   0.56465E-17   0.83399E-17   0.11475E-16   0.16997E-16   0.25879E-16   0.36484E-16   0.48813E-16
 16   0.34288E-17   0.56863E-17   0.83943E-17   0.11545E-16   0.17093E-16   0.26012E-16   0.36660E-16   0.48813E-16
 17   0.34540E-17   0.57242E-17   0.84460E-17   0.11611E-16   0.17184E-16   0.26140E-16   0.36660E-16   0.48813E-16
 18   0.34781E-17   0.57603E-17   0.84952E-17   0.11675E-16   0.17271E-16   0.26140E-16   0.36660E-16   0.48813E-16
 19   0.35010E-17   0.57948E-17   0.85423E-17   0.11736E-16   0.17354E-16   0.26140E-16   0.36660E-16   0.48813E-16
 20   0.35230E-17   0.58278E-17   0.85874E-17   0.11794E-16   0.17354E-16   0.26140E-16   0.36660E-16   0.48813E-16
 21   0.35441E-17   0.58594E-17   0.86306E-17   0.11794E-16   0.17354E-16   0.26140E-16   0.36660E-16   0.48813E-16
 22   0.35644E-17   0.58899E-17   0.86722E-17   0.11794E-16   0.17354E-16   0.26140E-16   0.36660E-16   0.48813E-16
 23   0.35838E-17   0.59191E-17   0.86722E-17   0.11794E-16   0.17354E-16   0.26140E-16   0.36660E-16   0.48813E-16
 24   0.36026E-17   0.59191E-17   0.86722E-17   0.11794E-16   0.17354E-16   0.26140E-16   0.36660E-16   0.48813E-16

       0.1600E-05    0.2000E-05    0.2600E-05    0.3500E-05    0.5000E-05    0.8000E-05    0.1500E-04
  1   0.39980E-16   0.59220E-16   0.94712E-16   0.16818E-15   0.31245E-15   0.74992E-15   0.24636E-14
  2   0.50950E-16   0.75536E-16   0.12104E-15   0.20741E-15   0.39842E-15   0.95430E-15   0.31143E-14
  3   0.56727E-16   0.84119E-16   0.13443E-15   0.22998E-15   0.44164E-15   0.10584E-14   0.34489E-14
  4   0.60047E-16   0.89667E-16   0.14418E-15   0.24654E-15   0.47158E-15   0.11295E-14   0.36789E-14
  5   0.62294E-16   0.93232E-16   0.15063E-15   0.25950E-15   0.49646E-15   0.11828E-14   0.38553E-14
  6   0.63975E-16   0.95816E-16   0.15507E-15   0.26854E-15   0.51746E-15   0.12286E-14   0.39920E-14
  7   0.65310E-16   0.97826E-16   0.15841E-15   0.27492E-15   0.53379E-15   0.12710E-14   0.41064E-14
  8   0.66413E-16   0.99461E-16   0.16107E-15   0.27979E-15   0.54524E-15   0.13078E-14   0.42091E-14
  9   0.67350E-16   0.10084E-15   0.16326E-15   0.28369E-15   0.55385E-15   0.13379E-14   0.43048E-14
 10   0.68163E-16   0.10202E-15   0.16512E-15   0.28693E-15   0.56067E-15   0.13615E-14   0.43958E-14
 11   0.68880E-16   0.10305E-15   0.16673E-15   0.28968E-15   0.56629E-15   0.13790E-14   0.44819E-14
 12   0.69521E-16   0.10397E-15   0.16815E-15   0.29208E-15   0.57103E-15   0.13929E-14   0.45554E-14
 13   0.69871E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.45922E-14
 14   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46223E-14
 15   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46475E-14
 16   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
 17   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
 18   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
 19   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
 20   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
 21   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
 22   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
 23   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
 24   0.70201E-16   0.10445E-15   0.16886E-15   0.29319E-15   0.57303E-15   0.13978E-14   0.46692E-14
```

```
PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO. 1 OF CORRECTION PARAMETERS

   SIZE      CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.    COR. W     COR. P
2.500E-07  1.589   0.008   0.0210      0.0244      59.8767     5.673   40.1233   45.0424     3.718    54.9576
3.500E-07  1.414   0.049   0.1359      0.1308      59.4811     5.612   40.5189   54.0537     4.831    45.9463
4.500E-07  1.320   0.212   0.5826      0.5215      60.0682     5.702   39.9318   57.8917     5.373    48.1083
5.500E-07  1.261   0.597   1.5937      1.3928      61.2279     5.885   38.7721   60.0837     5.705    39.9163
7.000E-07  1.205   2.119   5.4026      4.7063      62.9750     6.172   37.0250   62.0046     6.011    37.9954
9.000E-07  1.159   2.985   7.0896      6.1893      65.5043     6.611   34.4957   64.5233     6.437    35.4767
1.100E-06  1.130   3.582   7.9408      6.9556      67.8036     7.080   32.1964   66.7758     6.845    33.2248
1.300E-06  1.110   3.283   6.7915      6.0162      69.9588     7.470   30.0412   68.6506     7.205    31.3494
1.600E-06  1.090   6.865  12.9352     11.5594      72.6349     8.050   27.3651   71.1920     7.731    28.6080
2.000E-06  1.072   7.164  12.0059     10.8313      75.6592     8.777   24.3408   74.1311     8.399    25.8689
2.600E-06  1.055  11.940  16.9421     15.7103      79.3911     9.811   20.6089   77.4871     9.262    22.5129
3.500E-06  1.041  10.447  12.0625     11.8169      83.2307    11.092   16.7693   80.6474    10.202    19.3526
5.000E-06  1.029  14.925  11.9052     12.6892      88.4146    13.389   11.5854   85.4531    11.975    14.5469
8.000E-06  1.018  14.925   4.0698      6.6496      96.0395    20.056    3.9605   92.3770    15.989     7.6230
1.500E-05  1.010  20.899   0.5220      4.8066      99.6372    34.904    0.3628   96.0648    20.096     3.9352

   EFFICIENCY - STATED = 99.00     COMPUTED = 79.9829     CONVERGENCE OBTAINED


   ADJUSTED NO-RAP EFF. =  85.4759
   MMD OF INLET SIZE DISTRIBUTION =  3.987E+00
   SIGMAP OF INLET SIZE DISTRIBUTION =  2.165E+00
   LOG-NORMAL GOODNESS OF FIT =  0.985
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.063E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.804E+00
   LOG-NORMAL GOODNESS OF FIT =  0.995
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 11.985


   SIGMAG=    0.000  WITH  0.000 SNEAKAGE OVER    4.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  82.8902
   CORRECTED MMD OF EFFLUENT =  2.481E+00
   CORRECTED SIGMAP OF EFFLUENT =  1.969E+00
   LOG-NORMAL GOODNESS OF FIT =  0.990
   CORRECTED PRECIPITATION RATE PARAMETER =   10.97
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED    IDEAL UNADJUSTED         NO-RAP            RAPPING PUFF        NO-RAP+RAP PUFF      RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)    EFFICIENCY(%)      DM/DLOGD(MG/DSCM)   DM/DLOGD(MG/DSCM)   DM/DLOGD(MG/DSCM)   DISTRIBUTION(%)   DIAM.(M)
 2.440E+00             3.248E+01            2.812E-02            1.040E-02            3.851E-02          4.360E-02        2.500E-07
 2.586E+00             3.405E+01            2.564E-01            3.435E-02            2.908E-01          1.022E-01        3.500E-07
 2.782E+00             3.610E+01            1.418E+00            7.727E-02            1.495E+00          1.784E-01        4.500E-07
 2.995E+00             3.826E+01            4.746E+00            1.401E-01            4.886E+00          2.642E-01        5.500E-07
 3.336E+00             4.155E+01            1.020E+01            2.673E-01            1.046E+01          7.953E-01        7.000E-07
 3.800E+00             4.576E+01            1.725E+01            4.906E-01            1.774E+01          1.132E+00        9.000E-07
 4.272E+00             4.973E+01            2.365E+01            7.550E-01            2.440E+01          1.424E+00        1.100E-06
 4.746E+00             5.342E+01            2.392E+01            1.042E+00            2.496E+01          1.661E+00        1.300E-06
 5.461E+00             5.849E+01            2.795E+01            1.474E+00            2.942E+01          3.831E+00        1.600E-06
 6.407E+00             6.435E+01            3.249E+01            2.040E+00            3.453E+01          4.234E+00        2.000E-06
 7.836E+00             7.168E+01            2.966E+01            2.740E+00            3.240E+01          8.791E+00        2.600E-06
 9.948E+00             7.984E+01            2.277E+01            3.507E+00            2.627E+01          1.044E+01        3.500E-06
 1.339E+01             8.841E+01            1.594E+01            4.075E+00            2.002E+01          1.709E+01        5.000E-06
 2.006E+01             9.604E+01            4.326E+00            4.001E+00            8.327E+00          2.114E+01        8.000E-06
 3.490E+01             9.964E+01            4.089E-01            4.027E+00            4.436E+00          2.887E+01        1.500E-05
```

```
************************************************************************************************
*                                                                                              *
*                            SUMMARY TABLE OF ESP OPERATING                                    *
*                              PARAMETERS AND PERFORMANCE                                      *
*                                                                                              *
*                                                                                              *
*                                  DATA SET NUMBER   1                                         *
*                                                                                              *
*        ESP PERFORMANCE:     EFFICIENCY =  82.8902 %     SCA =  1.610E+01 M**2/(M**3/SEC)     *
*                                                                                              *
*        ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.011E+04 V                        *
*                                   AVG. CURRENT DENSITY =   10.34 NA/CM**2                    *
*                                   RESISTIVITY =  1.000E+09 OHM-CM                            *
*                                                                                              *
*        SIZE DISTRIBUTIONS:     INLET MMD =  3.987E+00 UM     INLET SIGMAP =  2.165E+00       *
*                                OUTLET MMD =  2.481E+00 UM     OUTLET SIGMAP =  1.969E+00     *
*                                                                                              *
*        NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.00 /SECTION     GAS VELOCITY SIGMAG = 0.00
*                                 RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00  *
*                                                                                              *
************************************************************************************************
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PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  2 OF CORRECTION PARAMETERS

   SIZE      CCF  INLET %  OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W     COR. P
 2.500E-07  1.589   0.008    0.0186       0.0218    55.6046     5.044   44.3954   40.2773    3.202    59.7227
 3.500E-07  1.414   0.049    0.1202       0.1179    55.1910     4.986   44.8090   49.5831    4.254    50.4169
 4.500E-07  1.320   0.212    0.5166       0.4732    55.7356     5.062   44.2644   53.4867    4.755    46.5133
 5.500E-07  1.261   0.597    1.4190       1.2708    56.8430     5.220   43.1570   55.6608    5.052    44.3392
 7.000E-07  1.205   2.119    4.8421       4.3230    58.5153     5.465   41.4847   57.5127    5.317    42.4873
 9.000E-07  1.159   2.985    6.4184       5.7404    60.9581     5.842   39.0419   59.9444    5.683    40.0556
 1.100E-06  1.130   3.582    7.2618       6.5130    63.1894     6.208   36.8106   62.1274    6.031    37.8726
 1.300E-06  1.110   3.283    6.2760       5.6881    65.2944     6.574   34.7056   63.9427    6.336    36.0573
 1.600E-06  1.090   6.865   12.1309      11.0665    67.9168     7.062   32.0832   66.4259    6.779    33.5741
 2.000E-06  1.072   7.164   11.4797      10.5502    70.9042     7.669   29.0958   69.3253    7.341    30.6747
 2.600E-06  1.055  11.940   16.6809      15.6689    74.6330     8.521   25.3670   72.6658    8.057    27.3342
 3.500E-06  1.041  10.447   12.3687      12.1210    78.5035     9.549   21.4965   75.8344    8.822    24.1656
 5.000E-06  1.029  14.925   13.1924      13.6928    83.9504    11.364   16.0496   80.8905   10.280    19.1095
 8.000E-06  1.018  14.925    5.7287       7.7055    93.0306    16.546    6.9694   89.2463   13.852    10.7537
 1.500E-05  1.010  20.899    1.5461       5.0512    98.6567    26.773    1.3433   94.9656   18.566     5.0344

   EFFICIENCY - STATED = 99.00     COMPUTED = 79.9829     CONVERGENCE OBTAINED


   ADJUSTED NO-RAP EFF. =  81.8427
   MMD OF INLET SIZE DISTRIBUTION =  3.987E+00
   SIGMAP OF INLET SIZE DISTRIBUTION =  2.165E+00
   LOG-NORMAL GOODNESS OF FIT =  0.985
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.273E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.871E+00
   LOG-NORMAL GOODNESS OF FIT =  0.995
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 10.598


   SIGMAG=    0.100  WITH  0.100 SNEAKAGE OVER    4.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  79.1710
   CORRECTED MMD OF EFFLUENT =  2.573E+00
   CORRECTED SIGMAP OF EFFLUENT =  1.976E+00
   LOG-NORMAL GOODNESS OF FIT =  0.991
   CORRECTED PRECIPITATION RATE PARAMETER =    9.74
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED       NO-RAP           RAPPING PUFF      NO-RAP+RAP PUFF    RAPPING PUFF     PARTICLE
MIG. VEL.(CM/SEC)    EFFICIENCY(%)    DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
  2.440E+00           3.248E+01          3.111E-02          1.074E-02          4.185E-02          4.360E-02      2.500E-07
  2.586E+00           3.405E+01          2.836E-01          3.549E-02          3.191E-01          1.022E-01      3.500E-07
  2.782E+00           3.610E+01          1.571E+00          7.984E-02          1.651E+00          1.784E-01      4.500E-07
  2.995E+00           3.826E+01          5.283E+00          1.447E-01          5.428E+00          2.642E-01      5.500E-07
  3.336E+00           4.155E+01          1.143E+01          2.761E-01          1.170E+01          7.953E-01      7.000E-07
  3.800E+00           4.576E+01          1.953E+01          5.069E-01          2.003E+01          1.132E+00      9.000E-07
  4.272E+00           4.973E+01          2.704E+01          7.801E-01          2.782E+01          1.424E+00      1.100E-06
  4.746E+00           5.342E+01          2.764E+01          1.076E+00          2.871E+01          1.661E+00      1.300E-06
  5.461E+00           5.849E+01          3.277E+01          1.523E+00          3.429E+01          3.831E+00      1.600E-06
  6.407E+00           6.435E+01          3.883E+01          2.107E+00          4.094E+01          4.234E+00      2.000E-06
  7.836E+00           7.168E+01          3.651E+01          2.831E+00          3.934E+01          8.791E+00      2.600E-06
  9.948E+00           7.984E+01          2.919E+01          3.624E+00          3.281E+01          1.044E+01      3.500E-06
  1.339E+01           8.841E+01          2.209E+01          4.211E+00          2.630E+01          1.709E+01      5.000E-06
  2.006E+01           9.604E+01          7.613E+00          4.134E+00          1.175E+01          2.114E+01      8.000E-06
  3.490E+01           9.964E+01          1.514E+00          4.161E+00          5.675E+00          2.887E+01      1.500E-05
```

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******************************************************************************************************
*                                                                                                    *
*                                 SUMMARY TABLE OF ESP OPERATING                                     *
*                                  PARAMETERS AND PERFORMANCE                                        *
*                                                                                                    *
*                                                                                                    *
*                                      DATA SET NUMBER   2                                           *
*                                                                                                    *
*         ESP PERFORMANCE:     EFFICIENCY =  79.1710 %     SCA =  1.610E+01 M**2/(M**3/SEC)          *
*                                                                                                    *
*         ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.011E+04 V                             *
*                                    AVG. CURRENT DENSITY =   10.34 NA/CM**2                         *
*                                    RESISTIVITY =  1.000E+09 OHM-CM                                 *
*                                                                                                    *
*         SIZE DISTRIBUTIONS:     INLET MMD =  3.987E+00 UM     INLET SIGMAP =  2.165E+00            *
*                                 OUTLET MMD =  2.573E+00 UM     OUTLET SIGMAP =  1.976E+00          *
*                                                                                                    *
*         NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.10 /SECTION     GAS VELOCITY SIGMAG = 0.10
*                                  RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00       *
*                                                                                                    *
******************************************************************************************************
STOP  011111
```

APPENDIX K

OUTPUT DATA FOR EXAMPLE 3 (REVISION 2)

```
                    ****************************************
                    *                                      *
                    *           E.P.A. ESP MODEL           *
                    *                                      *
                    *    T.E.R.L.-R.T.P. AND SO.R.I.       *
                    *                                      *
                    *      REVISION II, AUG., 1979         *
                    *                                      *
                    ****************************************

PRINTOUT OF INPUT DATA FOR DATA SET NUMBER  1


DATA ON CARD NUMBER   1

NENDPT = 16   NDATA =  1

DATA ON CARD NUMBER   2

LAB ESP; SCA=82FT2/1000ACFM;CALCULATED V-I FOR EACH ELECTRICAL SECTION

DATA ON CARD NUMBER   3

NEST =  2  NDIST =  1  NVI =  4  NX = 15  NY = 15  NITER =  1  NCALC =  0  NRAPD =  1  NEFF =  1  NTEMP =  1  NONID =  2

DATA ON CARD NUMBER   4

NN =  5  NUMINC =  3

DATA ON CARD NUMBER   5

IFINAL = 20  JI1 =  2  JI2 = 21  VISKIP = 1  VISAME =  2

DATA ON CARD NUMBER   6

DL =  0.06500 GRN/ACF  PL =  10.0000 FT  FTAO = 99.00000 %  DD =  1000.00 KG/M**3  EPS =  5.100E+00
VRATIO =   1.0300  US = 0.000165 M**2/V-SEC  FPATH =   1.0000  EBD = 1500000. V/M  RHOCGS =  1.00E+09 OHM-CM

DATA ON CARD NUMBER   7

ABNUCK( 1) = 0.00  AZIGGY( 1) = 0.00  AZNUMS( 1) =  4.0
ABNUCK( 2) = 0.10  AZIGGY( 2) = 0.10  AZNUMS( 2) =  4.0

DATA ON CARD NUMBER   8

ENDPT( 1) =    0.200 UM   ENDPT( 2) =    0.300 UM   ENDPT( 3) =    0.400 UM   ENDPT( 4) =    0.500 UM   ENDPT( 5) =    0.600 UM
ENDPT( 6) =    0.800 UM   ENDPT( 7) =    1.000 UM   ENDPT( 8) =    1.200 UM   ENDPT( 9) =    1.400 UM   ENDPT(10) =    1.800 UM

DATA ON CARD NUMBER   9

ENDPT(11) =    2.200 UM   ENDPT(12) =    3.000 UM   ENDPT(13) =    4.000 UM   ENDPT(14) =    6.000 UM   ENDPT(15) =   10.000 UM
ENDPT(16) =   20.000 UM

DATA ON CARD NUMBER  10

PRCU( 1) =   0.0000 %   PRCU( 2) =   0.0076 %   PRCU( 3) =   0.0563 %   PRCU( 4) =   0.2682 %   PRCU( 5) =   0.8652 %
PRCU( 6) =   2.9845 %   PRCU( 7) =   5.9695 %   PRCU( 8) =   9.5515 %   PRCU( 9) =  12.8350 %   PRCU(10) =  19.7004 %

DATA ON CARD NUMBER  11

PRCU(11) =  26.8643 %   PRCU(12) =  38.8042 %   PRCU(13) =  49.2516 %   PRCU(14) =  64.1765 %   PRCU(15) =  79.1014 %
PRCU(16) = 100.0000 %

DATA ON CARD NUMBER  12

NUMBEC =  3    LSECT( 1) =  6  LSECT( 2) =  6  LSECT( 3) = 12

DATA ON CARD NUMBER  13

AS( 1) =  6.2500E+00 FT**2  VOS( 1) =  4.0000E+04 V  TCS( 1) =  6.2500E-05 A  WLS( 1) =  6.2500E+00 FT
ACS( 1) =  4.6875E-02 IN  BS( 1) =  5.0000E+00 IN  NWS( 1) =  5.0000E+00

DATA ON CARD NUMBER  14

SYS( 1) =  2.5000E+00 IN .VGS( 1) =  3.0533E+02 FT**3/MIN  VGASS( 1) =  4.8853E+00 FT/SEC  TEMPS( 1) =  7.6000E+01 F
PS( 1) =  1.0000E+00 ATM  VISS( 1) =  1.8000E-05 KG/M-SEC  LINCS( 1) =  4.1667E-01 FT
```

```
DATA ON CARD NUMBER  15

RFS( 1) =  9.0000E-01  START1( 1) =  6.0000E-05 A/M**2  START2( 1) =  2.0000E-05 A/M**2

START3( 1) =  2.0000E-05 A/M**2  VSTAR( 1) =  3.8000E+04 V

DATA ON CARD NUMBER  16

AS( 2) =  6.2500E+00 FT**2  VOS( 2) =  4.0800E+04 V  TCS( 2) =  6.2500E-05 A  NLS( 2) =  6.2500E+00 FT

ACS( 2) =  4.6875E-02 IN  BS( 2) =  5.0000E+00 IN  NWS( 2) =  5.0000E+00

DATA ON CARD NUMBER  17

SVS( 2) =  2.5000E+00 IN  VOS( 2) =  3.0533E+02 FT**3/MIN  VGASS( 2) =  4.8853E+00 FT/SEC  TEMPS( 2) =  7.6000E+01 F

PS( 2) =  1.0000E+00 ATM  VISS( 2) =  1.8000E-05 KG/M-SEC  LINCS( 2) =  4.1667E-01 FT

DATA ON CARD NUMBER  18

RFS( 2) =  9.0000E-01  START1( 2) =  6.0000E-05 A/M**2  START2( 2) =  2.0000E-05 A/M**2

START3( 2) =  2.0000E-05 A/M**2  VSTAR( 2) =  3.8000E+04 V

DATA ON CARD NUMBER  19

AS( 3) =  1.2500E+01 FT**2  VOS( 3) =  3.9600E+04 V  TCS( 3) =  1.2500E-04 A  NLS( 3) =  1.2500E+01 FT

ACS( 3) =  4.6875E-02 IN  BS( 3) =  5.0000E+00 IN  NWS( 3) =  1.0000E+01

DATA ON CARD NUMBER  20

SVS( 3) =  2.5000E+00 IN  VOS( 3) =  3.0533E+02 FT**3/MIN  VGASS( 3) =  4.8853E+00 FT/SEC  TEMPS( 3) =  7.6000E+01 F

PS( 3) =  1.0000E+00 ATM  VISS( 3) =  1.8000E-05 KG/M-SEC  LINCS( 3) =  4.1667E-01 FT

DATA ON CARD NUMBER  21

RFS( 3) =  9.0000E-01  START1( 3) =  6.0000E-05 A/M**2  START2( 3) =  2.0000E-05 A/M**2

START3( 3) =  2.0000E-05 A/M**2  VSTAR( 3) =  3.8000E+04 V
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CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  1

                    VW = -3.7698E+04  ACDNTY =  6.0000E-05  AEPLT = -1,7773E+05

                    VW = -3.8347E+04  ACDNTY =  8.0000E-05  AEPLT = -1,8647E+05

                    VW = -3.8965E+04  ACDNTY =  1.0000E-04  AEPLT = -1,9469E+05

                    VW = -3.9557E+04  ACDNTY =  1.2000E-04  AEPLT = -2,0248E+05

                    VW = -4.0125E+04  ACDNTY =  1.4000E-04  AEPLT = -2,0988E+05

                    VW = -4.0673E+04  ACDNTY =  1.6000E-04  AEPLT = -2,1697E+05

                    VW = -4.1204E+04  ACDNTY =  1.8000E-04  AEPLT = -2,2376E+05

                    VW = -4.0802E+04  ACDNTY =  1.6478E-04  AEPLT = -2,1861E+05


INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


LAB ESP; SCA=82FT2/1000ACFM;CALCULATED V-I FOR EACH ELECTRICAL SECTION

CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2        APPLIED VOLTAGE =  4.080E+04 VOLTS        TOTAL CURRENT =  9.578E-05 AMPS
WIRE TO PLATE =  1.270E-01 M           CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  5.024E-05 AMP/M           CURRENT DENSITY =  1.648E-04 AMP/M2       DEPOSIT E FIELD =  1.648E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M        GAS FLOW RATE =  1.444E-01 M3/SEC         GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.436E+02 M/SEC     PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC        LENGTH INCR. =0.12708435 M                INPUT EFF./INCR. = 17.46

RIOVR     ERAVG      EPLT       AFID        CMCD     MMD        WEIGHT     DUST LAYER  J(PART)     J(ION)    INCR. NO.

0.8184   2.056E+05  2.1861E+05  1.1816E+13  13.5   7.28E-06   5.695E-06  5.094E-04  3.27E-08   1.65E-04      1
0.7343   2.056E+05  2.1861E+05  1.1822E+13  12.1   4.31E-06   8.586E-06  7.680E-04  6.77E-08   1.65E-04      2
0.7147   2.056E+05  2.1861E+05  1.1824E+13  11.8   2.94E-06   8.928E-06  7.986E-04  8.37E-08   1.65E-04      3
0.7067   2.056E+05  2.1861E+05  1.1825E+13  11.6   2.29E-06   8.655E-06  7.742E-04  9.19E-08   1.65E-04      4
0.7038   2.056E+05  2.1861E+05  1.1825E+13  11.6   1.94E-06   8.152E-06  7.292E-04  9.60E-08   1.65E-04      5
0.7038   2.056E+05  2.1861E+05  1.1826E+13  11.6   1.65E-06   7.566E-06  6.768E-04  9.77E-08   1.65E-04      6
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            CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  2

                        VW = -3.7698E+04  ACDNTY =  6.0000E-05  AEPLT = -1.7773E+05

                        VW = -3.8347E+04  ACDNTY =  8.0000E-05  AEPLT = -1.8647E+05

                        VW = -3.8965E+04  ACDNTY =  1.0000E-04  AEPLT = -1.9469E+05

                        VW = -3.9557E+04  ACDNTY =  1.2000E-04  AEPLT = -2.0248E+05

                        VW = -4.0125E+04  ACDNTY =  1.4000E-04  AEPLT = -2.0988E+05

                        VW = -4.0673E+04  ACDNTY =  1.6000E-04  AEPLT = -2.1697E+05

                        VW = -4.1204E+04  ACDNTY =  1.8000E-04  AEPLT = -2.2376E+05

                        VW = -4.0802E+04  ACDNTY =  1.6478E-04  AEPLT = -2.1861E+05

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2          APPLIED VOLTAGE =  4.080E+04 VOLTS      TOTAL CURRENT =  9.578E-05 AMPS
WIRE TO PLATE =  1.270E-01 M             CORONA WIRE RADIUS =  1.191E-03 M       CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  5.024E-05 AMP/M             CURRENT DENSITY =  1.648E-04 AMP/M2     DEPOSIT E FIELD =  1.648E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M          GAS FLOW RATE =  1.444E-01 M3/SEC       GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                  PRESSURE =  1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.436E+02 M/SEC     PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC          LENGTH INCR. =0.12708435 M              INPUT EFF./INCR. = 17.46

RIOVR    ERAVG       EPLT        AFID       CMCD    MMD        WEIGHT     DUST LAYER  J(PART)     J(ION)   INCR. NO.

0.7054  2.056E+05  2.1861E+05  1.1826E+13   11.6   1.47E-06   6.967E-06   6.232E-04   9.79E-08   1.65E-04      7
0.7082  2.056E+05  2.1861E+05  1.1826E+13   11.7   1.34E-06   6.388E-06   5.714E-04   9.71E-08   1.65E-04      8
0.7117  2.056E+05  2.1861E+05  1.1826E+13   11.7   1.22E-06   5.846E-06   5.229E-04   9.56E-08   1.65E-04      9
0.7159  2.056E+05  2.1861E+05  1.1826E+13   11.8   1.11E-06   5.347E-06   4.783E-04   9.37E-08   1.65E-04     10
0.7204  2.056E+05  2.1861E+05  1.1826E+13   11.9   1.02E-06   4.894E-06   4.377E-04   9.15E-08   1.65E-04     11
0.7252  2.056E+05  2.1861E+05  1.1826E+13   12.0   9.55E-07   4.484E-06   4.011E-04   8.91E-08   1.65E-04     12

            CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  3

                        VW = -3.7701E+04  ACDNTY =  6.0000E-05  AEPLT = -1.7777E+05

                        VW = -3.8350E+04  ACDNTY =  8.0000E-05  AEPLT = -1.8651E+05

                        VW = -3.8968E+04  ACDNTY =  1.0000E-04  AEPLT = -1.9473E+05
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                         VH = -3.9560E+04  ACDNTY =  1.2000E-04  AEPLT = -2.0252E+05

                         VH = -4.0128E+04  ACDNTY =  1.4000E-04  AEPLT = -2.0993E+05

                         VH = -3.9601E+04  ACDNTY =  1.2142E-04  AEPLT = -2.0306E+05


CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  1.5250 M

COLLECTION AREA =  1.162E+00 M2        APPLIED VOLTAGE =  3.960E+04 VOLTS        TOTAL CURRENT =  1.412E-04 AMPS
WIRE TO PLATE =  1.270E-01 M           CORONA WIRE RADIUS =  1.191E-03 M         CORONA WIRE LENGTH =  3.812E+00 M
CURRENT/M =  3.702E-05 AMP/M           CURRENT DENSITY =  1.214E-04 AMP/M2       DEPOSIT E FIELD =  1.218E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M        GAS FLOW RATE =  1.444E-01 M3/SEC         GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                PRESSURE =   1.000 ATM                    VISCOSITY =  1.800E-05 KG/M-SEC
ION-MOBILITY =  1.795E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.436E+02 M/SEC      PART. PATH PARAM. =  5.700F-08 M
DUST WEIGHT =  2.150E-05 KG/SEC        LENGTH INCR. =0.12708435 M                INPUT EFF./INCR. = 17.46


RIOVR     ERAVG        EPLT         AFID       CMCD     MMD        WEIGHT      DUST LAYER   J(PART)       J(ION)    INCR. NO.

0.6785   1.963E+05   2.0306E+05   9.2742E+12    8.2   8.78E-07   3.827E-06   3.423E-04   8.02E-08    1.21E-04       13
0.6844   1.963E+05   2.0306E+05   9.2742E+12    8.3   8.28E-07   3.529E-06   3.157E-04   7.76E-08    1.21E-04       14
0.6903   1.963E+05   2.0306E+05   9.2742E+12    8.4   7.87E-07   3.262E-06   2.918E-04   7.50E-08    1.21E-04       15
0.6962   1.963E+05   2.0306E+05   9.2743E+12    8.5   7.53E-07   3.023E-06   2.704E-04   7.25E-08    1.21E-04       16
0.7021   1.963E+05   2.0306E+05   9.2743E+12    8.5   7.25E-07   2.804E-06   2.508E-04   7.01E-08    1.21E-04       17
0.7081   1.963E+05   2.0306E+05   9.2744E+12    8.6   7.00E-07   2.603E-06   2.329E-04   6.76E-08    1.21E-04       18
0.7143   1.963E+05   2.0306E+05   9.2744E+12    8.7   6.77E-07   2.420E-06   2.165E-04   6.51E-08    1.21E-04       19
0.7206   1.963E+05   2.0306E+05   9.2745E+12    8.8   6.56E-07   2.254E-06   2.016E-04   6.25E-08    1.21E-04       20
0.7269   1.963E+05   2.0306E+05   9.2745E+12    8.8   6.39E-07   2.104E-06   1.882E-04   6.01E-08    1.21F-04       21
0.7331   1.963E+05   2.0306E+05   9.2746E+12    8.9   6.24E-07   1.967F-06   1.760E-04   5.77F-08    1.21E-04       22
0.7393   1.963E+05   2.0306E+05   9.2746E+12    9.0   6.11E-07   1.843E-06   1.649E-04   5.55E-08    1.21E-04       23
0.7454   1.963E+05   2.0306E+05   9.2746E+12    9.1   6.00E-07   1.730E-06   1.547E-04   5.34E-08    1.21E-04       24

DESIGN EFFICIENCY = 99.00     UNCORRECTED COMPUTED EFFICIENCY = 75.83
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CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHARGN OR CHGSUM

SUM OF CLASSICAL FIELD AND DIFFUSIONAL CHARGES USED FOR PARTICLE CHARGING

INCREMENT NO.     Q/QSATF FOR INDICATED PARTICLE SIZES

    0.2500E-06   0.3500E-06   0.4500E-06   0.5500E-06   0.7000E-06   0.9000E-06   0.1100E-05   0.1300E-05
  1   1.1602        1.0713       0.9970       0.9378       0.8703       0.8062       0.7605       0.7262
  2   1.4208        1.3024       1.2075       1.1335       1.0506       0.9731       0.9184       0.8777
  3   1.5699        1.4336       1.3265       1.2438       1.1517       1.0662       1.0062       0.9618
  4   1.6741        1.5251       1.4092       1.3203       1.2216       1.1305       1.0668       1.0196
  5   1.7538        1.5949       1.4721       1.3784       1.2747       1.1792       1.1125       1.0633
  6   1.8182        1.6511       1.5227       1.4250       1.3172       1.2181       1.1490       1.0981
  7   1.8720        1.6980       1.5649       1.4638       1.3528       1.2503       1.1792       1.1269
  8   1.9180        1.7380       1.6008       1.4968       1.3824       1.2776       1.2048       1.1512
  9   1.9582        1.7729       1.6321       1.5255       1.4084       1.3013       1.2269       1.1722
 10   1.9937        1.8037       1.6596       1.5507       1.4313       1.3221       1.2463       1.1907
 11   2.0256        1.8313       1.6843       1.5733       1.4516       1.3406       1.2636       1.2070
 12   2.0545        1.8562       1.7065       1.5936       1.4700       1.3572       1.2790       1.2217
 13   2.0730        1.8719       1.7203       1.6060       1.4809       1.3669       1.2879       1.2300
 14   2.0903        1.8866       1.7332       1.6176       1.4912       1.3760       1.2963       1.2378
 15   2.1067        1.9005       1.7453       1.6285       1.5009       1.3846       1.3041       1.2451
 16   2.1222        1.9135       1.7568       1.6389       1.5100       1.3927       1.3115       1.2520
 17   2.1368        1.9260       1.7676       1.6486       1.5186       1.4003       1.3185       1.2585
 18   2.1507        1.9377       1.7779       1.6579       1.5268       1.4075       1.3251       1.2647
 19   2.1640        1.9489       1.7878       1.6667       1.5346       1.4144       1.3251       1.2647
 20   2.1767        1.9596       1.7971       1.6751       1.5420       1.4144       1.3251       1.2647
 21   2.1888        1.9698       1.8060       1.6831       1.5420       1.4144       1.3251       1.2647
 22   2.2003        1.9796       1.8060       1.6831       1.5420       1.4144       1.3251       1.2647
 23   2.2114        1.9796       1.8060       1.6831       1.5420       1.4144       1.3251       1.2647
 24   2.2221        1.9796       1.8060       1.6831       1.5420       1.4144       1.3251       1.2647

    0.1600E-05   0.2000E-05   0.2600E-05   0.3500E-05   0.5000E-05   0.8000E-05   0.1500E-04
  1   0.6852        0.6528       0.6175       0.5850       0.5545       0.5253       0.5002
  2   0.8329        0.7915       0.7507       0.7133       0.6785       0.6456       0.6176
  3   0.9131        0.8682       0.8241       0.7839       0.7466       0.7115       0.6817
  4   0.9681        0.9208       0.8743       0.8321       0.7930       0.7563       0.7253
  5   1.0096        0.9603       0.9121       0.8682       0.8278       0.7899       0.7580
  6   1.0426        0.9918       0.9421       0.8969       0.8554       0.8165       0.7830
  7   1.0699        1.0177       0.9667       0.9205       0.8780       0.8383       0.8049
  8   1.0929        1.0396       0.9875       0.9404       0.8971       0.8566       0.8226
  9   1.1128        1.0584       1.0054       0.9574       0.9134       0.8723       0.8378
 10   1.1302        1.0749       1.0210       0.9723       0.9276       0.8860       0.8510
 11   1.1456        1.0895       1.0349       0.9855       0.9402       0.8980       0.8627
 12   1.1594        1.1025       1.0472       0.9972       0.9514       0.9087       0.8731
 13   1.1671        1.1097       1.0539       1.0034       0.9572       0.9142       0.8783
 14   1.1743        1.1164       1.0601       1.0092       0.9627       0.9194       0.8832
 15   1.1811        1.1227       1.0660       1.0147       0.9678       0.9242       0.8877
 16   1.1875        1.1286       1.0715       1.0198       0.9726       0.9287       0.8920
 17   1.1935        1.1342       1.0766       1.0247       0.9726       0.9287       0.8920
 18   1.1992        1.1342       1.0766       1.0247       0.9726       0.9287       0.8920
 19   1.1992        1.1342       1.0766       1.0247       0.9726       0.9287       0.8920
 20   1.1992        1.1342       1.0766       1.0247       0.9726       0.9287       0.8920
 21   1.1992        1.1342       1.0766       1.0247       0.9726       0.9287       0.8920
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22	1.1992	1.1342	1.0766	1.0247	0.9726	0.9287	0.8920
23	1.1992	1.1342	1.0766	1.0247	0.9726	0.9287	0.8920
24	1.1992	1.1342	1.0766	1.0247	0.9726	0.9287	0.8920

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 CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT

INCREMENT        CHARGE FOR INDICATED PARTICLE SIZES

         0.2500E-06    0.3500E-06    0.4500E-06    0.5500E-06    0.7000E-06    0.9000E-06    0.1100E-05    0.1300E-05
   1    0.18957E-17   0.30959E-17   0.45155E-17   0.61461E-17   0.89755E-17   0.13447E-16   0.18700E-16   0.24728E-16
   2    0.23215E-17   0.37635E-17   0.54688E-17   0.74288E-17   0.10835E-16   0.16229E-16   0.22582E-16   0.29881E-16
   3    0.25650E-17   0.41429E-17   0.60078E-17   0.81514E-17   0.11878E-16   0.17783E-16   0.24743E-16   0.32746E-16
   4    0.27353E-17   0.44071E-17   0.63823E-17   0.86524E-17   0.12599E-16   0.18855E-16   0.26231E-16   0.34719E-16
   5    0.28656E-17   0.46089E-17   0.66676E-17   0.90333E-17   0.13146E-16   0.19667E-16   0.27356E-16   0.36202E-16
   6    0.29707E-17   0.47713E-17   0.68968E-17   0.93390E-17   0.13585E-16   0.20316E-16   0.28254E-16   0.37387E-16
   7    0.30586E-17   0.49067E-17   0.70876E-17   0.95930E-17   0.13948E-16   0.20853E-16   0.28996E-16   0.38366E-16
   8    0.31338E-17   0.50225E-17   0.72504E-17   0.98094E-17   0.14258E-16   0.21309E-16   0.29625E-16   0.39195E-16
   9    0.31995E-17   0.51232E-17   0.73919E-17   0.99973E-17   0.14526E-16   0.21703E-16   0.30169E-16   0.39911E-16
  10    0.32576E-17   0.52123E-17   0.75168E-17   0.10163E-16   0.14761E-16   0.22050E-16   0.30646E-16   0.40538E-16
  11    0.33097E-17   0.52920E-17   0.76284E-17   0.10311E-16   0.14972E-16   0.22359E-16   0.31070E-16   0.41095E-16
  12    0.33568E-17   0.53640E-17   0.77292E-17   0.10444E-16   0.15161E-16   0.22636E-16   0.31451E-16   0.41595E-16
  13    0.33870E-17   0.54093E-17   0.77914E-17   0.10525E-16   0.15274E-16   0.22798E-16   0.31670E-16   0.41878E-16
  14    0.34154E-17   0.54518E-17   0.78498E-17   0.10601E-16   0.15380E-16   0.22950E-16   0.31875E-16   0.42143E-16
  15    0.34421E-17   0.54919E-17   0.79048E-17   0.10673E-16   0.15479E-16   0.23093E-16   0.32067E-16   0.42392E-16
  16    0.34674E-17   0.55297E-17   0.79568E-17   0.10740E-16   0.15573E-16   0.23227E-16   0.32249E-16   0.42627E-16
  17    0.34914E-17   0.55656E-17   0.80059E-17   0.10804E-16   0.15662E-16   0.23355E-16   0.32421E-16   0.42849E-16
  18    0.35141E-17   0.55996E-17   0.80526E-17   0.10865E-16   0.15747E-16   0.23476E-16   0.32583E-16   0.43059E-16
  19    0.35358E-17   0.56320E-17   0.80971E-17   0.10923E-16   0.15827E-16   0.23590E-16   0.32583E-16   0.43059E-16
  20    0.35565E-17   0.56629E-17   0.81394E-17   0.10978E-16   0.15903E-16   0.23590E-16   0.32583E-16   0.43059E-16
  21    0.35762E-17   0.56924E-17   0.81798E-17   0.11030E-16   0.15903E-16   0.23590E-16   0.32583E-16   0.43059E-16
  22    0.35951E-17   0.57206E-17   0.81798E-17   0.11030E-16   0.15903E-16   0.23590E-16   0.32583E-16   0.43059E-16
  23    0.36133E-17   0.57206E-17   0.81798E-17   0.11030E-16   0.15903E-16   0.23590E-16   0.32583E-16   0.43059E-16
  24    0.36307E-17   0.57206E-17   0.81798E-17   0.11030E-16   0.15903E-16   0.23590E-16   0.32583E-16   0.43059E-16

         0.1600E-05    0.2000E-05    0.2600E-05    0.3500E-05    0.5000E-05    0.8000E-05    0.1500E-04
   1    0.35189E-16   0.51782E-16   0.82271E-16   0.14050E-15   0.27061E-15   0.65395E-15   0.21832E-14
   2    0.42590E-16   0.62791E-16   0.10001E-15   0.17132E-15   0.33116E-15   0.80371E-15   0.26954E-14
   3    0.46689E-16   0.68873E-16   0.10979E-15   0.18826E-15   0.36437E-15   0.88568E-15   0.29752E-14
   4    0.49503E-16   0.73041E-16   0.11648E-15   0.19984E-15   0.38703E-15   0.94153E-15   0.31657E-14
   5    0.51624E-16   0.76180E-16   0.12151E-15   0.20853E-15   0.40401E-15   0.98334E-15   0.33081E-14
   6    0.53313E-16   0.78674E-16   0.12550E-15   0.21542E-15   0.41746E-15   0.10164E-14   0.34207E-14
   7    0.54706E-16   0.80730E-16   0.12879E-15   0.22108E-15   0.42851E-15   0.10435E-14   0.35129E-14
   8    0.55884E-16   0.82466E-16   0.13156E-15   0.22585E-15   0.43780E-15   0.10663E-14   0.35908E-14
   9    0.56900E-16   0.83961E-16   0.13395E-15   0.22995E-15   0.44577E-15   0.10859E-14   0.36567E-14
  10    0.57789E-16   0.85268E-16   0.13603E-15   0.23352E-15   0.45271E-15   0.11029E-14   0.37143E-14
  11    0.58578E-16   0.86426E-16   0.13787E-15   0.23668E-15   0.45885E-15   0.11179E-14   0.37651E-14
  12    0.59284E-16   0.87462E-16   0.13952E-15   0.23950E-15   0.46432E-15   0.11312E-14   0.38104E-14
  13    0.59678E-16   0.88030E-16   0.14040E-15   0.24100E-15   0.46716E-15   0.11381E-14   0.38332E-14
  14    0.60047E-16   0.88562E-16   0.14123E-15   0.24239E-15   0.46982E-15   0.11445E-14   0.38549E-14
  15    0.60393E-16   0.89061E-16   0.14201E-15   0.24370E-15   0.47232E-15   0.11504E-14   0.38744E-14
  16    0.60719E-16   0.89531E-16   0.14274E-15   0.24493E-15   0.47466E-15   0.11561E-14   0.38932E-14
  17    0.61027E-16   0.89975E-16   0.14343E-15   0.24609E-15   0.47466E-15   0.11561E-14   0.38932E-14
  18    0.61319E-16   0.89975E-16   0.14343E-15   0.24609E-15   0.47466E-15   0.11561E-14   0.38932E-14
  19    0.61319E-16   0.89975E-16   0.14343E-15   0.24609E-15   0.47466E-15   0.11561E-14   0.38932E-14
  20    0.61319E-16   0.89975E-16   0.14343E-15   0.24609E-15   0.47466E-15   0.11561E-14   0.38932E-14
  21    0.61319E-16   0.89975E-16   0.14343E-15   0.24609E-15   0.47466E-15   0.11561E-14   0.38932E-14
  22    0.61319E-16   0.89975E-16   0.14343E-15   0.24609E-15   0.47466E-15   0.11561E-14   0.38932E-14
  23    0.61319E-16   0.89975E-16   0.14343E-15   0.24609E-15   0.47466E-15   0.11561E-14   0.38932E-14
  24    0.61319E-16   0.89975E-16   0.14343E-15   0.24609E-15   0.47466E-15   0.11561E-14   0.38932E-14
```

```
PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  1 OF CORRECTION PARAMETERS

   SIZE      CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W    COR. P
2.500E-07  1.589  0.008   0.0162        0.0196      60.4177      5.757  39.5823   45.0462    3.719     54.9538
3.500E-07  1.414  0.049   0.1085        0.1077      58.4853      5.461  41.5147   52.8613    4.672     47.1387
4.500E-07  1.320  0.212   0.4771        0.4395      58.0627      5.398  41.9373   55.8074    5.073     44.1926
5.500E-07  1.261  0.597   1.3291        1.1952      58.5306      5.468  41.4694   57.3450    5.292     42.6550
7.000E-07  1.205  2.119   4.6137        4.1335      59.4501      5.607  40.5499   58.4446    5.455     41.5554
9.000E-07  1.159  2.985   6.2119        5.5731      61.2373      5.887  38.7627   60.2208    5.726     39.7792
1.100E-06  1.130  3.582   7.1198        6.4035      62.9766      6.172  37.0234   61.9115    5.996     38.0885
1.300E-06  1.110  3.283   6.2122        5.6399      64.7594      6.479  35.2406   63.4039    6.244     36.5961
1.600E-06  1.090  6.865  12.1510       11.1047      67.0329      6.893  32.9671   65.5377    6.617     34.4623
2.000E-06  1.072  7.164  11.6408       10.7093      69.7332      7.424  30.2668   68.1497    7.107     31.8503
2.600E-06  1.055 11.940  17.1454       16.0948      73.2526      8.192  26.7474   71.2798    7.749     28.7202
3.500E-06  1.041 10.447  12.8117       12.5131      77.1581      9.172  22.8419   74.4812    8.484     25.5188
5.000E-06  1.029 14.925  13.6244       14.0606      82.9965     11.005  17.0035   79.9277    9.975     20.0723
8.000E-06  1.018 14.925   5.5649        7.5235      93.0549     16.567   6.9451   89.2598   13.859     10.7402
1.500E-05  1.010 20.899   0.9735        4.4820      99.1324     29.488   0.8676   95.4306   19.168      4.5694

    EFFICIENCY - STATED = 99.00     COMPUTED = 75.8299     CONVERGENCE OBTAINED


    ADJUSTED NO-RAP EFF. =  81.3734
    MMD OF INLET SIZE DISTRIBUTION =  3.987E+00
    SIGMAP OF INLET SIZE DISTRIBUTION =  2.165E+00
    LOG-NORMAL GOODNESS OF FIT =  0.985
    MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.218E+00
    SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.825E+00
    LOG-NORMAL GOODNESS OF FIT =  0.995
    PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 10.439


    SIGMAG=    0.000  WITH  0.000 SNEAKAGE OVER    4.000  STAGES
    NTEMP = 1
    RMMD =  6.00
    RSIGMA = 2.50
    CORR. EFF. =  78.6939
    CORRECTED MMD OF EFFLUENT =  2.565E+00
    CORRECTED SIGMAP OF EFFLUENT =  1.955E+00
    LOG-NORMAL GOODNESS OF FIT =  0.992
    CORRECTED PRECIPITATION RATE PARAMETER =    9.60
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP            RAPPING PUFF        NO-RAP+RAP PUFF      RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)   EFFICIENCY(%)     DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
  2.476E+00          3.288E+01           2.774E-02          1.077E-02           3.851E-02          4.360E-02        2.500E-07
  2.517E+00          3.331E+01           2.627E-01          3.559E-02           2.983E-01          1.022E-01        3.500E-07
  2.633E+00          3.455E+01           1.489E+00          8.007E-02           1.569E+00          1.784E-01        4.500E-07
  2.782E+00          3.611E+01           5.077E+00          1.451E-01           5.222E+00          2.642E-01        5.500E-07
  3.031E+00          3.861E+01           1.117E+01          2.769E-01           1.144E+01          7.953E-01        7.000E-07
  3.383E+00          4.200E+01           1.939E+01          5.084E-01           1.989E+01          1.132E+00        9.000E-07
  3.745E+00          4.528E+01           2.719E+01          7.823E-01           2.798E+01          1.424E+00        1.100E-06
  4.116E+00          4.845E+01           2.806E+01          1.080E+00           2.914E+01          1.661E+00        1.300E-06
  4.676E+00          5.290E+01           3.367E+01          1.527E+00           3.520E+01          3.831E+00        1.600E-06
  5.419E+00          5.820E+01           4.040E+01          2.113E+00           4.251E+01          4.234E+00        2.000E-06
  6.543E+00          6.512E+01           3.850E+01          2.839E+00           4.133E+01          8.791E+00        2.600E-06
  8.226E+00          7.340E+01           3.101E+01          3.634E+00           3.465E+01          1.044E+01        3.500E-06
  1.101E+01          8.300E+01           2.340E+01          4.223E+00           2.762E+01          1.709E+01        5.000E-06
  1.657E+01          9.305E+01           7.586E+00          4.146E+00           1.173E+01          2.114E+01        8.000E-06
  2.949E+01          9.913E+01           9.780E-01          4.173E+00           5.151E+00          2.887E+01        1.500E-05
```

```
**************************************************************************************************
*                                                                                                *
*                                SUMMARY TABLE OF ESP OPERATING                                  *
*                                 PARAMETERS AND PERFORMANCE                                     *
*                                                                                                *
*                                                                                                *
*                                     DATA SET NUMBER   1                                        *
*                                                                                                *
*       ESP PERFORMANCE:     EFFICIENCY =  78.6939 %     SCA =  1.610E+01 M**2/(M**3/SEC)        *
*                                                                                                *
*       ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.020E+04 V                           *
*                                  AVG. CURRENT DENSITY =   10.28 NA/CM**2                       *
*                                  RESISTIVITY =  1.000E+09 OHM-CM                               *
*                                                                                                *
*       SIZE DISTRIBUTIONS:     INLET MMD =  3.987E+00 UM     INLET SIGMAP =  2.165E+00          *
*                               OUTLET MMD =  2.565E+00 UM     OUTLET SIGMAP =  1.955E+00        *
*                                                                                                *
*       NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.00 /SECTION     GAS VELOCITY SIGMAG = 0.00
*                                RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00     *
*                                                                                                *
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PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  2 OF CORRECTION PARAMETFRS

   SIZE      CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W     COR. P
2.500E-07  1.589  0.008    0.0148        0.0179      56.1311     5.118   43.8689   40.5296    3.228    59.4704
3.500E-07  1.414  0.049    0.0988        0.0991      54.2253     4.854   45.7747   48.5172    4.124    51.4828
4.500E-07  1.320  0.212    0.4338        0.4064      53.7920     4.796   46.2080   51.5029    4.895    48.4971
5.500E-07  1.261  0.597    1.2108        1.1090      54.2255     4.854   45.7745   53.0221    4.693    46.9779
7.000E-07  1.205  2.119    4.2174        3.8494      55.0865     4.972   44.9135   54.0660    4.832    45.9340
9.000E-07  1.159  2.985    5.7151        5.2223      56.7880     5.212   43.2120   55.7562    5.065    44.2438
1.100E-06  1.130  3.582    6.5944        6.0384      58.4494     5.455   41.5506   57.3684    5.296    42.6316
1.300E-06  1.110  3.283    5.7957        5.3511      60.1622     5.717   39.8378   58.7863    5.506    41.2137
1.600E-06  1.090  6.865   11.4532       10.6336      62.3479     6.067   37.6521   60.8303    5.822    39.1697
2.000E-06  1.072  7.164   11.1228       10.3820      64.9577     6.514   35.0423   63.3506    6.235    36.6494
2.600E-06  1.055 11.940   16.7251       15.8719      68.3849     7.153   31.6151   66.3825    6.771    33.6175
3.500E-06  1.041 10.447   12.8663       12.6051      72.2046     7.953   27.7954   69.4877    7.373    30.5123
5.000E-06  1.029 14.925   14.4817       14.7625      78.1006     9.434   21.8994   74.9859    8.608    25.0141
8.000E-06  1.018 14.925    7.0835        8.5951      89.2881    13.876   10.7119   85.4362   11.968    14.5638
1.500E-05  1.010 20.899    2.1866        5.0562      97.6386    23.268    2.3614   93.8815   17.350     6.1185

   EFFICIENCY - STATED = 99.00     COMPUTED = 75.8299     CONVERGENCE OBTAINED

   ADJUSTED NO-RAP EFF. =  77.4303
   MMD OF INLET SIZE DISTRIBUTION =  3.987E+00
   SIGMAP OF INLET SIZE DISTRIBUTION =  2.165E+00
   LOG-NORMAL GOODNESS OF FIT =  0.985
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.423E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.889E+00
   LOG-NORMAL GOODNESS OF FIT =  0.994
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS =  9.246


   SIGMAG=    0.100  WITH  0.100 SNEAKAGE OVER    4.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  74.7107
   CORRECTED MMD OF EFFLUENT =  2.663E+00
   CORRECTED SIGMAP OF EFFLUENT =  1.968E+00
   LOG-NORMAL GOODNESS OF FIT =  0.992
   CORRECTED PRECIPITATION RATE PARAMETER =    8.54
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP           RAPPING PUFF      NO-RAP+RAP PUFF     RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)   EFFICIENCY(%)     DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)   DIAM.(M)
 2.476E+00           3.288E+01           3.074E-02          1.093E-02          4.167E-02          4.360E-02         2.500E-07
 2.517E+00           3.331E+01           2.897E-01          3.613E-02          3.258E-01          1.022E-01         3.500E-07
 2.633E+00           3.455E+01           1.640E+00          8.127E-02          1.722E+00          1.784E-01         4.500E-07
 2.782E+00           3.611E+01           5.604E+00          1.473E-01          5.751E+00          2.642E-01         5.500E-07
 3.031E+00           3.861E+01           1.237E+01          2.811E-01          1.265E+01          7.953E-01         7.000E-07
 3.383E+00           4.200E+01           2.161E+01          5.160E-01          2.213E+01          1.132E+00         9.000E-07
 3.745E+00           4.528E+01           3.052E+01          7.940E-01          3.131E+01          1.424E+00         1.100E-06
 4.116E+00           4.845E+01           3.172E+01          1.096E+00          3.282E+01          1.661E+00         1.300E-06
 4.676E+00           5.290E+01           3.845E+01          1.550E+00          4.000E+01          3.831E+00         1.600E-06
 5.419E+00           5.820E+01           4.677E+01          2.145E+00          4.891E+01          4.234E+00         2.000E-06
 6.543E+00           6.512E+01           4.550E+01          2.882E+00          4.838E+01          8.791E+00         2.600E-06
 8.226E+00           7.340E+01           3.774E+01          3.689E+00          4.143E+01          1.044E+01         3.500E-06
 1.101E+01           8.300E+01           3.014E+01          4.286E+00          3.442E+01          1.709E+01         5.000E-06
 1.657E+01           9.305E+01           1.170E+01          4.208E+00          1.591E+01          2.114E+01         8.000E-06
 2.949E+01           9.913E+01           2.662E+00          4.235E+00          6.897E+00          2.887E+01         1.500E-05
```

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*****************************************************************************************************
*                                                                                                   *
*                          SUMMARY TABLE OF ESP OPERATING                                           *
*                           PARAMETERS AND PERFORMANCE                                              *
*                                                                                                   *
*                                                                                                   *
*                               DATA SET NUMBER   2                                                 *
*                                                                                                   *
*    ESP PERFORMANCE:    EFFICIENCY =  74,7107 %     SCA =  1.610E+01 M**2/(M**3/SEC)               *
*                                                                                                   *
*    ELECTRICAL CONDITIONS:    AVG, APPLIED VOLTAGE =  4,020E+04 V                                  *
*                              AVG, CURRENT DENSITY =   10,28 NA/CM**2                              *
*                              RESISTIVITY =  1.000E+09 OHM-CM                                      *
*                                                                                                   *
*    SIZE DISTRIBUTIONS:    INLET MMD =  3,987F+00 UM     INLET SIGMAP =  2.165E+00                 *
*                           OUTLET MMD =  2.663E+00 UM     OUTLET SIGMAP =  1.968E+00               *
*                                                                                                   *
*    NONIDEAL PARAMETERS:    GAS SNEAKAGE FRACTION = 0.10 /SECTION     GAS VELOCITY SIGMAG = 0,10   *
*                            RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2,500E+00            *
*                                                                                                   *
*****************************************************************************************************
STOP  011111
```

APPENDIX L

OUTPUT DATA FOR EXAMPLE 3 (REVISION 1)

```
****************************************
*                                      *
*          E.P.A. ESP MODEL            *
*     T.E.R.L.-R.T.P. AND SO.R.I.      *
*      REVISION I,JAN. 1, 1978         *
*                                      *
****************************************

PRINTOUT OF INPUT DATA FOR DATA SET NUMBER  1


DATA ON CARD NUMBER   1

NENDPT = 16   NDATA =  1

DATA ON CARD NUMBER   2

LAB ESP; SCA=82FT2/1000ACFM;CALCULATED V-I FOR EACH ELECTRICAL SECTION

DATA ON CARD NUMBER   3

NEST =  2  NDIST =  1  NVI =  2  NX = 15  NY = 15  NITER =  1  NCALC =  0  NRAPD =  1  NEFF =  1  NTEMP =  1  NONID =  2

DATA ON CARD NUMBER   4

NN = 10  NUMINC = 20

DATA ON CARD NUMBER   5

IFINAL = 20  JI1 =  2  JI2 = 21  VISKIP = 1  VISAME =  2

DATA ON CARD NUMBER   6

DL =  0.06500 GRN/ACF  PL =  10.0000 FT  ETAO = 99.00000 %  DD =  1000.00 KG/M**3  EPS =  5.100E+00
VRATIO =   1.0300  US = 0.000165 M**2/V-SEC  FPATH =   1.0000  EBD = 1500000. V/M  RHOCGS =  1.00E+09 OHM-CM

DATA ON CARD NUMBER   7

ABNUCK( 1) = 0.00  AZIGGY( 1) = 0.00  AZNUMS( 1) =  4.0
```

```
ASNUCK( 2) = 0.10  AZIGGY( 2) = 0.10  AZNUMS( 2) =  4.0

DATA ON CARD NUMBER   8

ENDPT( 1) =    0.200 UM   ENDPT( 2) =    0.300 UM   ENDPT( 3) =    0.400 UM   ENDPT( 4) =    0.500 UM   ENDPT( 5) =    0.600 UM
ENDPT( 6) =    0.800 UM   ENDPT( 7) =    1.000 UM   ENDPT( 8) =    1.200 UM   ENDPT( 9) =    1.400 UM   ENDPT(10) =    1.800 UM

DATA ON CARD NUMBER   9

ENDPT(11) =    2.200 UM   ENDPT(12) =    3.000 UM   ENDPT(13) =    4.000 UM   ENDPT(14) =    6.000 UM   ENDPT(15) =  10.000 UM
ENDPT(16) =.  20.000 UM

DATA ON CARD NUMBER  10

PRCU( 1) =   0.0000 %   PRCU( 2) =   0.0076 %   PRCU( 3) =   0.0563 %   PRCU( 4) =   0.2682 %   PRCU( 5) =   0.8652 %
PRCU( 6) =   2.9845 %   PRCU( 7) =   5.9695 %   PRCU( 8) =   9.5515 %   PRCU( 9) =  12.8350 %   PRCU(10) =  19.7004 %

DATA ON CARD NUMBER  11

PRCU(11) =  26.8643 %   PRCU(12) =  38.8042 %   PRCU(13) =  49.2516 %   PRCU(14) =  64.1765 %   PRCU(15) =  79.1014 %
PRCU(16) = 100.0000 %

DATA ON CARD NUMBER  12

NUMSEC =  3    LSECT( 1) =  6  LSECT( 2) =  6  LSECT( 3) = 12

DATA ON CARD NUMBER  13

AS( 1) =  6.2500E+00 FT**2  VOS( 1) =  4.0800E+04 V  TCS( 1) =  6.2500E-05 A  WLS( 1) =  6.2500E+00 FT
ACS( 1) =  4.6875E-02 IN  BS( 1) =  5.0000E+00 IN  NWS( 1) =  5.0000E+00

DATA ON CARD NUMBER  14

SYS( 1) =  2.5000E+00 IN  VGS( 1) =  3.0533E+02 FT**3/MIN  VGASS( 1) =  4.8853E+00 FT/SEC  TEMPS( 1) =  7.6000E+01 F
PS( 1) =  1.0000E+00 ATM  VTSS( 1) =  1.8000E-05 KG/M-SEC  LINCS( 1) =  4.1667E-01 FT
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DATA ON CARD NUMBER  15

RFS( 1) =  9.0000E-01  START1( 1) =  6.0000F-05 A/M**2  START2( 1) =  2.0000E-05 A/M**2
START3( 1) =  2.0000E-05 A/M**2  VSTAR( 1) =  3.8000E+04 V

DATA ON CARD NUMBER  16

AS( 2) =  6.2500E+00 FT**2  VOS( 2) =  4.0000E+04 V  TCS( 2) =  6.2500E-05 A  NLS( 2) =  6.2500E+00 FT
ACS( 2) =  4.6875F-02 IN  BS( 2) =  5.0000E+00 IN  NNS( 2) =  5.0000E+00

DATA ON CARD NUMBER  17

SYS( 2) =  2.5000E+00 IN  VGS( 2) =  3.0533E+02 FT**3/MIN  VGASS( 2) =  4.8853E+00 FT/SEC  TEMPS( 2) =  7.6000E+01 F
PS( 2) =  1.0000E+00 ATM  VISS( 2) =  1.8000E-05 KG/M-SEC  LINCS( 2) =  4.1667E-01 FT

DATA ON CARD NUMBER  18

RFS( 2) =  9.0000F-01  START1( 2) =  6.0000F-05 A/M**2  START2( 2) =  2.0000E-05 A/M**2
START3( 2) =  2.0000E-05 A/M**2  VSTAR( 2) =  3.8000E+04 V

DATA ON CARD NUMBFR  19

AS( 3) =  1.2500F+01 FT**2  VOS( 3) =  3.9600E+04 V  TCS( 3) =  1.2500E-04 A  NLS( 3) =  1.2500E+01 FT
ACS( 3) =  4.6875E-02 IN  BS( 3) =  5.0000E+00 IN  NNS( 3) =  1.0000F+01

DATA ON CARD NUMBER  20

SYS( 3) =  2.5000F+00 IN  VGS( 3) =  3.0533F+02 FT**3/MIN  VGASS( 3) =  4.8853E+00 FT/SEC  TEMPS( 3) =  7.6000E+01 F
PS( 3) =  1.0000E+00 ATM  VISS( 3) =  1.8000E-05 KG/M-SEC  LINCS( 3) =  4.1667E-01 FT

DATA ON CARD NUMBFR  21

RFS( 3) =  9.0000E-01  START1( 3) =  6.0000E-05 A/M**2  START2( 3) =  2.0000E-05 A/M**2
START3( 3) =  2.0000E-05 A/M**2  VSTAR( 3) =  3.8000E+04 V
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CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO. 1

                    VW = -3.8000E+04  ACDNTY =  6.0276E-05  AEPLT = -1.7902E+05

                    VW = -3.8206E+04  ACDNTY =  7.9337E-05  AEPLT = -1.8597E+05

                    VW = -3.8896E+04  ACDNTY =  9.9193E-05  AEPLT = -1.9435E+05

                    VW = -3.9513E+04  ACDNTY =  1.1908E-04  AEPLT = -2.0232E+05

                    VW = -4.0098E+04  ACDNTY =  1.3890E-04  AEPLT = -2.0993E+05

                    VW = -4.0656E+04  ACDNTY =  1.5874E-04  AEPLT = -2.1722E+05

                    VW = -4.1193E+04  ACDNTY =  1.7859E-04  AEPLT = -2.2424E+05

                    VW = -4.0711E+04  ACDNTY =  1.6251E-04  AEPLT = -2.1842E+05


INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


LAB ESP: SCA=82FT2/1000ACFM;CALCULATED V-I FOR EACH ELECTRICAL SECTION


CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2         APPLIED VOLTAGE =  4.080E+04 VOLTS        TOTAL CURRENT =  9.446E-05 AMPS
WIRE TO PLATE =  1.270E-01 M            CORONA WIRE RADIUS =  1.191E-03 M          CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  4.955E-05 AMP/M            CURRENT DENSITY =  1.625E-04 AMP/M2        DEPOSIT E FIELD =  1.695E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M         GAS FLOW RATE =  1.444E-01 M3/SEC          GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                 PRESSURE =   1.000 ATM                     VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  4.436E+02 M/SEC      PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC         LENGTH INCR. =0.12708435 M                 INPUT EFF./INCR. = 17.46

RIOVR     FRAVG       EPLT        AFID        CMCD     MMD        WEIGHT      DUST LAYER   J(PART)      J(ION)    INCR. NO.

0.8270   2.085E+05  2.1842E+05  2.1568E+13   13.4   7.29E-06   6.039E-06   5.402E-04   3.60E-08    1.62E-04      1
0.7546   2.085E+05  2.1842E+05  2.1575E+13   12.3   4.28E-06   8.888E-06   7.950E-04   7.28E-08    1.62E-04      2
0.7356   2.085E+05  2.1842E+05  2.1578E+13   12.0   2.92E-06   9.226E-06   8.252E-04   9.01E-08    1.62E-04      3
0.7278   2.085E+05  2.1842E+05  2.1579E+13   11.8   2.28E-06   8.922E-06   7.981E-04   9.91E-08    1.62E-04      4
0.7251   2.085E+05  2.1842E+05  2.1580E+13   11.8   1.93E-06   8.376E-06   7.492E-04   1.04E-07    1.62E-04      5
0.7292   2.085E+05  2.1842E+05  2.1581E+13   11.8   1.64E-06   7.745E-06   6.927E-04   1.05E-07    1.62E-04      6
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         CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  2

                   VW = -3.8000E+04  ACDNTY =  6.0276E-05  AEPLT = -1.7902E+05

                   VW = -3.8206E+04  ACDNTY =  7.9337E-05  AEPLT = -1.8597E+05

                   VW = -3.8896E+04  ACDNTY =  9.9103E-05  AEPLT = -1.9435E+05

                   VW = -3.9513E+04  ACDNTY =  1.1904E-04  AEPLT = -2.0232E+05

                   VW = -4.0098E+04  ACDNTY =  1.3890E-04  AEPLT = -2.0993E+05

                   VW = -4.0656E+04  ACDNTY =  1.5874E-04  AEPLT = -2.1722E+05

                   VW = -4.1193E+04  ACDNTY =  1.7859E-04  AEPLT = -2.2424E+05

                   VW = -4.0711E+04  ACDNTY =  1.6251E-04  AEPLT = -2.1842E+05


CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  0.7625 M

COLLECTION AREA =  5.812E-01 M2         APPLIED VOLTAGE =  4.080E+04 VOLTS       TOTAL CURRENT =  9.446E-05 AMPS
WIRE TO PLATE =  1.270E-01 M            CORONA WIRE RADIUS =  1.191E-03 M        CORONA WIRE LENGTH =  1.906E+00 M
CURRENT/M =  4.955E-05 AMP/M            CURRENT DENSITY =  1.625E-04 AMP/M2      DEPOSIT E FIELD =  1.625E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M         GAS FLOW RATE =  1.444E-01 M3/SEC        GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                 PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  4.436E+02 M/SEC     PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC         LENGTH INCR. =0.12708435 M               INPUT EFF./INCR. = 17.46

RIOVR     ERAVG       EPLT        APID       CMCD     MMD        WEIGHT     DUST LAYER   J(PART)      J(ION)    INCR. NO.

0.7270   2.085E+05  2.1842E+05  2.1581E+13   11.8   1.46E-06   7.103E-06   6.354E-04   1.05E-07    1.62E-04       7
0.7299   2.085E+05  2.1842E+05  2.1581E+13   11.9   1.33E-06   6.487E-06   5.803E-04   1.04E-07    1.62E-04       8
0.7336   2.085E+05  2.1842E+05  2.1582E+13   11.9   1.20E-06   5.914E-06   5.290E-04   1.03E-07    1.62E-04       9
0.7379   2.085E+05  2.1842E+05  2.1582E+13   12.0   1.09E-06   5.390E-06   4.821E-04   1.00E-07    1.62E-04      10
0.7426   2.085E+05  2.1842E+05  2.1582E+13   12.1   1.01E-06   4.916E-06   4.398E-04   9.78E-08    1.62E-04      11
0.7475   2.085E+05  2.1842E+05  2.1582E+13   12.2   9.44E-07   4.491E-06   4.017E-04   9.50E-08    1.62E-04      12

         CLEAN GAS VOLTAGE-CURRENT DENSITY-FIELD AT THE PLATE RELATIONSHIP FOR SECTION NO.  3

                   VW = -3.8000E+04  ACDNTY =  6.0277E-05  AEPLT = -1.7902E+05

                   VW = -3.8205E+04  ACDNTY =  7.9332E-05  AEPLT = -1.8596E+05

                   VW = -3.8896E+04  ACDNTY =  9.9192E-05  AEPLT = -1.9435E+05
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                            VW = -3.9512E+04  ACDNTY =  1.1904E-04  AFPLT = -2.0232E+05

                            VW = -4.0098E+04  ACDNTY =  1.3889E-04  AEPLT = -2.0993E+05

                            VW = -3.9514E+04  ACDNTY =  1.2081E-04  AFPLT = -2.0279E+05

CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  1.5250 M

COLLECTION AREA =  1.162E+00 M2         APPLIED VOLTAGE =  3.960E+04 VOLTS       TOTAL CURRENT =  1.404E-04 AMPS
WIRE TO PLATE =  1.270E-01 M            CORONA WIRE RADIUS =  1.191E-03 M        CORONA WIRE LENGTH =  3.812E+00 M
CURRENT/M =  3.684E-05 AMP/M            CURRENT DENSITY =  1.208E-04 AMP/M2      DEPOSIT E FIELD =  1.208E+03 VOLT/M
1/2 WIRE TO WIRE =  6.350E-02 M         GAS FLOW RATE =  1.444E-01 M3/SEC        GAS VELOCITY =  1.490E+00 M/SEC
TEMPERATURE = 297.222 K                 PRESSURE =   1.000 ATM                   VISCOSITY =  1.800E-05 KG/M-SEC
ION MOBILITY =  1.795E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  4.436E+02 M/SEC    PART. PATH PARAM. =  5.700E-08 M
DUST WEIGHT =  2.150E-05 KG/SEC         LENGTH INCR. =0.12708435 M               INPUT EFF./INCR. = 17.46

RIOVR     ERAVG        EPLT         AFID       CMCD      MMD        WEIGHT     DUST LAYER   J(PART)     J(ION)    INCR. NO.

0.7042   2.001E+05  2.0279E+05  1.7773E+13     8.5    8.66E-07    3.821E-06   3.418E-04   8.54E-08    1.21E-04      13
0.7102   2.001E+05  2.0279E+05  1.7773E+13     8.6    8.17E-07    3.515E-06   3.145E-04   8.25E-08    1.21E-04      14
0.7162   2.001E+05  2.0279E+05  1.7773E+13     8.7    7.77E-07    3.243E-06   2.901E-04   7.96E-08    1.21E-04      15
0.7222   2.001E+05  2.0279E+05  1.7773E+13     8.7    7.44E-07    2.999E-06   2.683E-04   7.69E-08    1.21E-04      16
0.7281   2.001E+05  2.0279E+05  1.7773E+13     8.8    7.17E-07    2.779E-06   2.485E-04   7.42E-08    1.21E-04      17
0.7341   2.001E+05  2.0279E+05  1.7773E+13     8.9    6.92E-07    2.576E-06   2.304E-04   7.15E-08    1.21E-04      18
0.7403   2.001E+05  2.0279E+05  1.7773E+13     8.9    6.69E-07    2.391E-06   2.139E-04   6.87E-08    1.21E-04      19
0.7466   2.001E+05  2.0279E+05  1.7774E+13     9.0    6.50E-07    2.223E-06   1.989E-04   6.59E-08    1.21E-04      20
0.7528   2.001E+05  2.0279E+05  1.7774E+13     9.1    6.33E-07    2.072E-06   1.853E-04   6.33E-08    1.21E-04      21
0.7591   2.001E+05  2.0279E+05  1.7774E+13     9.2    6.18E-07    1.935E-06   1.731E-04   6.07E-08    1.21E-04      22
0.7652   2.001E+05  2.0279E+05  1.7774E+13     9.2    6.06E-07    1.810E-06   1.619E-04   5.82E-08    1.21E-04      23
0.7711   2.001E+05  2.0279E+05  1.7774E+13     9.3    5.95E-07    1.697E-06   1.518E-04   5.59E-08    1.21E-04      24

DESIGN EFFICIENCY = 99.00      UNCORRECTED COMPUTED EFFICIENCY = 76.96
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CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHARGN OR CHGSUM

SUM OF CLASSICAL FIELD AND DIFFUSIONAL CHARGES USED FOR PARTICLE CHARGING

INCREMENT NO.     Q/QSATF FOR INDICATED PARTICLE SIZES

   0.2500E-06   0.3500E-06   0.4500E-06   0.5500E-06   0.7000E-06   0.9000E-06   0.1100E-05   0.1300E-05
 1  1.1496        1.0609       0.9872       0.9287       0.8622       0.7992       0.7543       0.7287
 2  1.4040        1.2869       1.1934       1.1208       1.0394       0.9636       0.9101       0.8706
 3  1.5514        1.4171       1.3119       1.2309       1.1408       1.0574       0.9988       0.9555
 4  1.6546        1.5082       1.3946       1.3076       1.2112       1.1224       1.0602       1.0143
 5  1.7336        1.5776       1.4575       1.3659       1.2647       1.1716       1.1066       1.0588
 6  1.7972        1.6335       1.5080       1.4125       1.3074       1.2108       1.1436       1.0941
 7  1.8503        1.6799       1.5499       1.4513       1.3427       1.2433       1.1741       1.1233
 8  1.8957        1.7195       1.5856       1.4841       1.3727       1.2707       1.1999       1.1478
 9  1.9352        1.7539       1.6165       1.5126       1.3986       1.2944       1.2221       1.1690
10  1.9700        1.7843       1.6437       1.5376       1.4213       1.3151       1.2415       1.1875
11  2.0013        1.8114       1.6680       1.5599       1.4416       1.3336       1.2587       1.2038
12  2.0295        1.8358       1.6899       1.5800       1.4597       1.3501       1.2742       1.2185
13  2.0477        1.8513       1.7035       1.5923       1.4706       1.3598       1.2831       1.2269
14  2.0647        1.8658       1.7163       1.6038       1.4809       1.3689       1.2915       1.2347
15  2.0808        1.8795       1.7283       1.6146       1.4905       1.3775       1.2993       1.2420
16  2.0959        1.8923       1.7396       1.6248       1.4995       1.3855       1.3067       1.2490
17  2.1103        1.9045       1.7503       1.6345       1.5081       1.3931       1.3137       1.2555
18  2.1239        1.9161       1.7604       1.6436       1.5162       1.4003       1.3202       1.2616
19  2.1369        1.9271       1.7701       1.6523       1.5238       1.4071       1.3202       1.2616
20  2.1493        1.9375       1.7793       1.6606       1.5311       1.4071       1.3202       1.2616
21  2.1610        1.9475       1.7880       1.6606       1.5311       1.4071       1.3202       1.2616
22  2.1723        1.9571       1.7880       1.6606       1.5311       1.4071       1.3202       1.2616
23  2.1831        1.9571       1.7880       1.6606       1.5311       1.4071       1.3202       1.2616
24  2.1831        1.9571       1.7880       1.6606       1.5311       1.4071       1.3202       1.2616

   0.1600E-05   0.2000E-05   0.2600E-05   0.3500E-05   0.5000E-05   0.8000E-05   0.1500E-04
 1  0.6835        0.6488       0.6144       0.5827       0.5530       0.5246       0.5002
 2  0.8267        0.7863       0.7466       0.7102       0.6764       0.6444       0.6172
 3  0.9080        0.8643       0.8215       0.7823       0.7461       0.7121       0.6812
 4  0.9642        0.9181       0.8730       0.8320       0.7941       0.7585       0.7285
 5  1.0065        0.9586       0.9118       0.8692       0.8300       0.7933       0.7623
 6  1.0402        0.9908       0.9425       0.8987       0.8588       0.8208       0.7891
 7  1.0679        1.0172       0.9677       0.9229       0.8817       0.8432       0.8109
 8  1.0912        1.0394       0.9889       0.9432       0.9012       0.8620       0.8292
 9  1.1113        1.0585       1.0071       0.9606       0.9179       0.8781       0.8448
10  1.1288        1.0751       1.0229       0.9756       0.9324       0.8920       0.8582
11  1.1442        1.0898       1.0368       0.9889       0.9451       0.9043       0.8701
12  1.1581        1.1029       1.0493       1.0008       0.9564       0.9151       0.8806
13  1.1658        1.1101       1.0560       1.0071       0.9624       0.9208       0.8860
14  1.1731        1.1169       1.0624       1.0131       0.9680       0.9261       0.8911
15  1.1799        1.1233       1.0683       1.0186       0.9732       0.9310       0.8958
16  1.1864        1.1293       1.0739       1.0238       0.9781       0.9356       0.9002
17  1.1924        1.1349       1.0791       1.0287       0.9827       0.9356       0.9002
18  1.1981        1.1349       1.0791       1.0287       0.9827       0.9356       0.9002
19  1.1981        1.1349       1.0791       1.0287       0.9827       0.9356       0.9002
20  1.1981        1.1349       1.0791       1.0287       0.9827       0.9356       0.9002
21  1.1981        1.1349       1.0791       1.0287       0.9827       0.9356       0.9002
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22  1.1981       1.1349       1.0791       1.0287       0.9827       0.9356       0.9002
23  1.1981       1.1349       1.0791       1.0287       0.9827       0.9356       0.9002
24  1.1981       1.1349       1.0791       1.0287       0.9827       0.9356       0.9002
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CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT

INCREMENT        CHARGE FOR INDICATED PARTICLE SIZES

          0.2500E-06     0.3500E-06     0.4500E-06     0.5500E-06     0.7000E-06     0.9000E-06     0.1100E-05     0.1300E-05
   1     0.19639E-17    0.32052E-17    0.46746E-17    0.63635E-17    0.92966E-17    0.13936E-16    0.19392E-16    0.25654E-16
   2     0.23984E-17    0.38879E-17    0.56511E-17    0.76796E-17    0.11208E-16    0.16802E-16    0.23397E-16    0.30981E-16
   3     0.26501E-17    0.42815E-17    0.62123E-17    0.84342E-17    0.12301E-16    0.18438E-16    0.25678E-16    0.34011E-16
   4     0.28265E-17    0.45565E-17    0.66036E-17    0.89594E-17    0.13061E-16    0.19571E-16    0.27257E-16    0.36106E-16
   5     0.29614E-17    0.47664E-17    0.69016E-17    0.93587E-17    0.13637E-16    0.20429E-16    0.28450E-16    0.37688E-16
   6     0.30701E-17    0.49351E-17    0.71406E-17    0.96785E-17    0.14097E-16    0.21114E-16    0.29401E-16    0.38946E-16
   7     0.31608E-17    0.50755E-17    0.73392E-17    0.99437E-17    0.14478E-16    0.21680E-16    0.30185E-16    0.39983E-16
   8     0.32383E-17    0.51951E-17    0.75081E-17    0.10169E-16    0.14802E-16    0.22158E-16    0.30848E-16    0.40859E-16
   9     0.33057E-17    0.52991E-17    0.76546E-17    0.10364E-16    0.15081E-16    0.22571E-16    0.31419E-16    0.41611E-16
  10     0.33653E-17    0.53908E-17    0.77836E-17    0.10536E-16    0.15324E-16    0.22933E-16    0.31918E-16    0.42269E-16
  11     0.34186E-17    0.54727E-17    0.78986E-17    0.10688E-16    0.15544E-16    0.23254E-16    0.32360E-16    0.42852E-16
  12     0.34668E-17    0.55465E-17    0.80022E-17    0.10826E-16    0.15740E-16    0.23542E-16    0.32757E-16    0.43373E-16
  13     0.34979E-17    0.55933E-17    0.80667E-17    0.10910E-16    0.15858E-16    0.23712E-16    0.32986E-16    0.43671E-16
  14     0.35271E-17    0.56371E-17    0.81271E-17    0.10989E-16    0.15968E-16    0.23870E-16    0.33201E-16    0.43950E-16
  15     0.35545E-17    0.56783E-17    0.81839E-17    0.11063E-16    0.16071E-16    0.24019E-16    0.33403E-16    0.44212E-16
  16     0.35804E-17    0.57173E-17    0.82375E-17    0.11133E-16    0.16169E-16    0.24160E-16    0.33593E-16    0.44458E-16
  17     0.36049E-17    0.57541E-17    0.82882E-17    0.11199E-16    0.16261E-16    0.24292E-16    0.33772E-16    0.44690E-16
  18     0.36282E-17    0.57890E-17    0.83362E-17    0.11262E-16    0.16349E-16    0.24417E-16    0.33941E-16    0.44909E-16
  19     0.36504E-17    0.58222E-17    0.83818E-17    0.11321E-16    0.16431E-16    0.24536E-16    0.33941E-16    0.44909E-16
  20     0.36715E-17    0.58538E-17    0.84252E-17    0.11378E-16    0.16510E-16    0.24536E-16    0.33941E-16    0.44909E-16
  21     0.36916E-17    0.58840E-17    0.84666E-17    0.11378E-16    0.16510E-16    0.24536E-16    0.33941E-16    0.44909E-16
  22     0.37109E-17    0.59128E-17    0.84666E-17    0.11378E-16    0.16510E-16    0.24536E-16    0.33941E-16    0.44909E-16
  23     0.37293E-17    0.59128E-17    0.84666E-17    0.11378E-16    0.16510E-16    0.24536E-16    0.33941E-16    0.44909E-16
  24     0.37293E-17    0.59128E-17    0.84666E-17    0.11378E-16    0.16510E-16    0.24536E-16    0.33941E-16    0.44909E-16


          0.1600E-05     0.2000E-05     0.2600E-05     0.3500E-05     0.5000E-05     0.8000E-05     0.1500E-04
   1     0.36539E-16    0.53813E-16    0.85584E-16    0.14632E-15    0.28215E-15    0.68276E-15    0.22825E-14
   2     0.44195E-16    0.65218E-16    0.10399E-15    0.17833E-15    0.34513E-15    0.83873E-15    0.28164E-14
   3     0.48543E-16    0.71686E-16    0.11442E-15    0.19644E-15    0.38071E-15    0.92675E-15    0.31175E-14
   4     0.51546E-16    0.76147E-16    0.12160E-15    0.20890E-15    0.40517E-15    0.98717E-15    0.33240E-14
   5     0.53809E-16    0.79506E-16    0.12700E-15    0.21826E-15    0.42351E-15    0.10325E-14    0.34786E-14
   6     0.55608E-16    0.82171E-16    0.13128E-15    0.22567E-15    0.43801E-15    0.10682E-14    0.36006E-14
   7     0.57088E-16    0.84362E-16    0.13479E-15    0.23174E-15    0.44989E-15    0.10975E-14    0.37002E-14
   8     0.58336E-16    0.86206E-16    0.13774E-15    0.23684E-15    0.45984E-15    0.11219E-14    0.37836E-14
   9     0.59407E-16    0.87787E-16    0.14027E-15    0.24120E-15    0.46835E-15    0.11428E-14    0.38546E-14
  10     0.60342E-16    0.89165E-16    0.14247E-15    0.24499E-15    0.47573E-15    0.11609E-14    0.39162E-14
  11     0.61169E-16    0.90383E-16    0.14441E-15    0.24832E-15    0.48223E-15    0.11769E-14    0.39703E-14
  12     0.61909E-16    0.91470E-16    0.14615E-15    0.25130E-15    0.48801E-15    0.11910E-14    0.40183E-14
  13     0.62325E-16    0.92073E-16    0.14709E-15    0.25290E-15    0.49106E-15    0.11984E-14    0.40430E-14
  14     0.62714E-16    0.92636E-16    0.14797E-15    0.25438E-15    0.49391E-15    0.12053E-14    0.40659E-14
  15     0.63079E-16    0.93163E-16    0.14880E-15    0.25578E-15    0.49658E-15    0.12117E-14    0.40874E-14
  16     0.63422E-16    0.93659E-16    0.14957E-15    0.25709E-15    0.49907E-15    0.12177E-14    0.41075E-14
  17     0.63745E-16    0.94126E-16    0.15030E-15    0.25832E-15    0.50142E-15    0.12177E-14    0.41075E-14
  18     0.64050E-16    0.94126E-16    0.15030E-15    0.25832E-15    0.50142E-15    0.12177E-14    0.41075E-14
  19     0.64050E-16    0.94126E-16    0.15030E-15    0.25832E-15    0.50142E-15    0.12177E-14    0.41075E-14
  20     0.64050E-16    0.94126E-16    0.15030E-15    0.25832E-15    0.50142E-15    0.12177E-14    0.41075E-14
  21     0.64050E-16    0.94126E-16    0.15030E-15    0.25832E-15    0.50142E-15    0.12177E-14    0.41075E-14
  22     0.64050E-16    0.94126E-16    0.15030E-15    0.25832E-15    0.50142E-15    0.12177E-14    0.41075E-14
  23     0.64050E-16    0.94126E-16    0.15030E-15    0.25832E-15    0.50142E-15    0.12177E-14    0.41075E-14
  24     0.64050E-16    0.94126E-16    0.15030E-15    0.25832E-15    0.50142E-15    0.12177E-14    0.41075E-14
```

```
PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  1 OF CORRECTION PARAMETERS

   SIZE      CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W     COR. P
2.500E-07  1.589  0.008   0.0167       0.0207       61.5779     5.942   38.4221   46.3205    3.865     53.6795
3.500E-07  1.414  0.049   0.1123       0.1109       59.6828     5.643   40.3172   54.1006    4.837     45.8994
4.500E-07  1.320  0.212   0.4931       0.4516       59.3004     5.584   40.6996   57.0617    5.251     42.9383
5.500E-07  1.261  0.597   1.3729       1.2265       59.7818     5.658   40.2182   58.6050    5.479     41.3950
7.000E-07  1.205  2.119   4.7520       4.2297       60.7853     5.815   39.2147   59.7872    5.659     40.2128
9.000E-07  1.159  2.985   6.3771       5.6849       62.6362     6.115   37.3638   61.6272    5.950     38.3728
1.100E-06  1.130  3.582   7.2861       6.5123       64.4255     6.420   35.5745   63.3683    6.238     36.6317
1.300E-06  1.110  3.283   6.3371       5.7199       66.2464     6.746   33.7536   64.9009    6.504     35.0991
1.600E-06  1.090  6.865  12.3416      11.2182       68.5606     7.188   31.4394   67.0765    6.901     32.9235
2.000E-06  1.072  7.164  11.7596      10.7662       71.2914     7.752   28.7086   69.7197    7.421     30.2803
2.600E-06  1.055 11.940  17.1893      16.0808       74.8217     8.567   25.1783   72.8635    8.102     27.1365
3.500E-06  1.041 10.447  12.7207      12.4193       78.7053     9.608   21.2947   76.0483    8.877     23.9517
5.000E-06  1.029 14.925  13.2607      13.7666       84.4609    11.565   15.5391   81.4150   10.453     18.5850
8.000E-06  1.018 14.925   5.1734       7.2808       93.9378    17.412    6.0622   90.1708   14.410      9.8292
1.500E-05  1.010 20.899   0.8075       4.5119       99.3242    31.040    0.6758   95.6500   19.473      4.3500

   EFFICIENCY - STATED = 99.00     COMPUTED = 76.9624     CONVERGENCE OBTAINED


   ADJUSTED NO-RAP EFF. =  82.5108
   MMD OF INLET SIZE DISTRIBUTION =  3.987E+00
   SIGMAP OF INLET SIZE DISTRIBUTION =  2.165E+00
   LOG-NORMAL GOODNESS OF FIT =  0.985
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.182E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.818E+00
   LOG-NORMAL GOODNESS OF FIT =  0.995
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 10.831


   SIGMAG=     0.000  WITH  0.000 SNEAKAGE OVER    4.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  79.8513
   CORRECTED MMD OF EFFLUENT =  2.546E+00
   CORRECTED SIGMAP OF EFFLUENT =  1.956E+00
   LOG-NORMAL GOODNESS OF FIT =  0.992
   CORRECTED PRECIPITATION RATE PARAMETER =    9.95
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED         NO-RAP            RAPPING PUFF       NO-RAP+RAP PUFF     RAPPING PUFF     PARTICLE
MIG. VEL.(CM/SEC)    EFFICIENCY(%)     DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 2.556E+00            3.373E+01            2.692E-02          1.069E-02           3.762E-02          4.360E-02        2.500E-07
 2.600E+00            3.420E+01            2.552E-01          3.533E-02           2.905E-01          1.022E-01        3.500E-07
 2.724E+00            3.550E+01            1.449E+00          7.948E-02           1.524E+00          1.784E-01        4.500E-07
 2.879E+00            3.709E+01            4.923E+00          1.441E-01           5.067E+00          2.642E-01        5.500E-07
 3.143E+00            3.971E+01            1.080E+01          2.749E-01           1.108E+01          7.953E-01        7.000E-07
 3.514E+00            4.321E+01            1.869E+01          5.046E-01           1.919E+01          1.132E+00        9.000E-07
 3.896E+00            4.659E+01            2.613E+01          7.765E-01           2.691E+01          1.424E+00        1.100E-06
 4.286E+00            4.984E+01            2.688E+01          1.071E+00           2.795E+01          1.661E+00        1.300E-06
 4.876E+00            5.439E+01            3.211E+01          1.516E+00           3.362E+01          3.831E+00        1.600E-06
 5.658E+00            5.979E+01            3.832E+01          2.098E+00           4.041E+01          4.234E+00        2.000E-06
 6.843E+00            6.677E+01            3.624E+01          2.818E+00           3.906E+01          8.791E+00        2.600E-06
 8.617E+00            7.502E+01            2.891E+01          3.607E+00           3.252E+01          1.044E+01        3.500E-06
 1.156E+01            8.446E+01            2.138E+01          4.192E+00           2.558E+01          1.709E+01        5.000E-06
 1.741E+01            9.394E+01            6.622E+00          4.115E+00           1.074E+01          2.114E+01        8.000E-06
 3.104E+01            9.932E+01            7.617E-01          4.142E+00           4.903E+00          2.887E+01        1.500E-05
```

```
                              SUMMARY TABLE OF ESP OPERATING
                               PARAMETERS AND PERFORMANCE


                                     DATA SET NUMBER   1

ESP PERFORMANCE:     EFFICIENCY =  79.8513 X     SCA =  1.610E+01 M**2/(M**3/SEC)

ELECTRICAL CONDITIONS:      AVG. APPLIED VOLTAGE =  4.011E+04 V

                            AVG. CURRENT DENSITY =   10.49 NA/CM**2

                            RESISTIVITY =  1.000E+09 OHM-CM

SIZE DISTRIBUTIONS:     INLET MMD =  3.987E+00 UM     INLFT SIGMAP =  2.165E+00

                        OUTLET MMD =  2.546E+00 UM     OUTLET SIGMAP =  1.956F+00

NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.00 /SECTION     GAS VELOCITY SIGMAG = 0.00

                         RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00
```

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PARTICLE SIZE RANGE STATISTICS


CORRECTIONS FOR NONIDEALITIES USING SET NO.  2 OF CORRECTION PARAMETERS

   SIZE      CCF   INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.    COR. W      COR. P
2.500E-07  1.589   0.008    0.0152        0.0184      57.2627      5.281   42.7373    41.7072     3.352     58.2928
3.500E-07  1.414   0.049    0.1017        0.1018      55.3868      5.014   44.6132    49.6955     4.268     50.3045
4.500E-07  1.320   0.212    0.4466        0.4164      54.9903      4.959   45.0097    52.7080     4.651     47.2920
5.500E-07  1.261   0.597    1.2457        1.1351      55.4376      5.021   44.5624    54.2378     4.856     45.7622
7.000E-07  1.205   2.119    4.3284        3.9304      56.3817      5.154   43.6183    55.3642     5.011     44.6358
9.000E-07  1.159   2.985    5.8493        5.3179      58.1498      5.411   41.8502    57.1211     5.260     42.8789
1.100E-06  1.130   3.582    6.7315        6.1335      59.8652      5.671   40.1348    58.7874     5.506     41.2126
1.300E-06  1.110   3.283    5.9005        5.4229      61.6215      5.949   38.3785    60.2497     5.731     39.7503
1.600E-06  1.090   6.865   11.6190       10.7416      63.8560      6.321   36.1440    62.3428     6.067     37.6572
2.000E-06  1.072   7.164   11.2346       10.4458      66.5080      6.795   33.4920    64.9056     6.504     35.0944
2.600E-06  1.055  11.940   16.7918       15.8904      69.9648      7.471   30.0352    67.9684     7.072     32.0316
3.500E-06  1.041  10.447   12.8226       12.5539      73.7878      8.317   26.2122    71.0789     7.706     28.9211
5.000E-06  1.029  14.925   14.2193       14.5430      79.6530      9.890   20.3470    76.5476     9.008     23.4524
8.000E-06  1.018  14.925    6.7369        8.3595      90.3599     14.531    9.6401    86.5193    12.448     13.4807
1.500E-05  1.010  20.899    1.9570        4.9892      98.0001     24.301    1.9999    94.2541    17.745      5.7459

   EFFICIENCY - STATED = 99.00     COMPUTED = 76.9624     CONVERGENCE OBTAINED


   ADJUSTED NO-RAP EFF. =  78.6433
   MMD OF INLET SIZE DISTRIBUTION =  3.987E+00
   SIGMAP OF INLET SIZE DISTRIBUTION =  2.165E+00
   LOG-NORMAL GOODNESS OF FIT =  0.985
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.386E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.881E+00
   LOG-NORMAL GOODNESS OF FIT =  0.995
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS =  9.590


   SIGMAG=    0.100  WITH  0.100 SNEAKAGE OVER    4.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  75.9318
   CORRECTED MMD OF EFFLUENT =  2.641E+00
   CORRECTED SIGMAP OF EFFLUENT =  1.967E+00
   LOG-NORMAL GOODNESS OF FIT =  0.992
   CORRECTED PRECIPITATION RATE PARAMETER =    8.85
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP            RAPPING PUFF       NO-RAP+RAP PUFF      RAPPING PUFF     PARTICLE
MIG. VEL.(CM/SEC)    EFFICIENCY(%)    DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 2.556E+00           3.373E+01           2.995E-02           1.090E-02           4.085E-02           4.360E-02        2.500E-07
 2.600E+00           3.420E+01           2.823E-01           3.602E-02           3.184E-01           1.022E-01        3.500E-07
 2.724E+00           3.550E+01           1.598E+00           8.103E-02           1.679E+00           1.784E-01        4.500E-07
 2.879E+00           3.709E+01           5.455E+00           1.469E-01           5.602E+00           2.642E-01        5.500E-07
 3.143E+00           3.971E+01           1.201E+01           2.802E-01           1.229E+01           7.953E-01        7.000E-07
 3.514E+00           4.321E+01           2.093E+01           5.145E-01           2.144E+01           1.132E+00        9.000E-07
 3.896E+00           4.659E+01           2.948E+01           7.917E-01           3.027E+01           1.424E+00        1.100E-06
 4.286E+00           4.984E+01           3.056E+01           1.092E+00           3.165E+01           1.661E+00        1.300E-06
 4.876E+00           5.439E+01           3.691E+01           1.545E+00           3.846E+01           3.831E+00        1.600E-06
 5.658E+00           5.979E+01           4.470E+01           2.139E+00           4.684E+01           4.234E+00        2.000E-06
 6.843E+00           6.677E+01           4.323E+01           2.873E+00           4.610E+01           8.791E+00        2.600E-06
 8.617E+00           7.502E+01           3.559E+01           3.678E+00           3.927E+01           1.044E+01        3.500E-06
 1.156E+01           8.446E+01           2.800E+01           4.274E+00           3.227E+01           1.709E+01        5.000E-06
 1.741E+01           9.394E+01           1.053E+01           4.195E+00           1.473E+01           2.114E+01        8.000E-06
 3.104E+01           9.932E+01           2.294E+00           4.223E+00           6.477E+00           2.887E+01        1.500E-05
```

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****************************************************************************************************
*                                                                                                  *
*                              SUMMARY TABLE OF ESP OPERATING                                      *
*                               PARAMETERS AND PERFORMANCE                                         *
*                                                                                                  *
*                                                                                                  *
*                                   DATA SFT NUMBER   2                                            *
*                                                                                                  *
*     ESP PERFORMANCE:     FFFICIENCY =  75.9318 %     SCA =  1.610E+01 M**2/(M**3/SEC)            *
*                                                                                                  *
*     ELECTRICAL CONDITIONS:     AVG, APPLIED VOLTAGE =  4.011E+04 V                               *
*                                AVG, CURRENT DENSITY =   10,49 NA/CM**2                           *
*                                RESISTIVITY =  1.000E+09 OHM-CM                                   *
*                                                                                                  *
*     SIZE DISTPIBUTIONS:     INLET MMD =  3,987F+00 UM     INLFT SIGMAP =  2.165F+00              *
*                             OUTLET MMD =  2.641E+00 UM     OUTLET SIGMAP =  1.967E+00            *
*                                                                                                  *
*     NONIDEAl PARAMETERS:     GAS SNEAKAGE FRACTION = 0,10 /SECTION     GAS VFLOCITY SIGMAG = 0,10 *
*                              RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00         *
*                                                                                                  *
****************************************************************************************************
STOP  011111
```

APPENDIX M

OUTPUT DATA FOR EXAMPLE 4 (REVISION 2)

```
                         ****************************************
                         *                                      *
                         *           E.P.A. ESP MODEL           *
                         *                                      *
                         *     I.E.R.L.-R.T.P. AND SO.R.I.      *
                         *                                      *
                         *       REVISION II, AUG., 1979        *
                         *                                      *
                         ****************************************

PRINTOUT OF INPUT DATA FOR DATA SET NUMBER  1


DATA ON CARD NUMBER   1

NENDPT = 14   NDATA =  1

DATA ON CARD NUMBER   2

FULL-SCALE,COLD-SIDE ESP; PLANT A; SCA=243FT2/1000ACFM;J=15.9UA/FT2

DATA ON CARD NUMBER   3

NEST =  1  NDIST =  1  NVI =  3  NX = 10  NY = 10  NITER =  3  NCALC =  0  NRAPD =  1  NEFF =  1  NTEMP =  1  NONID =  2

DATA ON CARD NUMBER   4

NN =  5  NUMINC =  3

DATA ON CARD NUMBER   5

DL =  1.96600 GPN/ACF  PL =  27.0000 FT  ETAD = 99.60000 %  DD =  2270.00 KG/M**3  EPS =  1.000E+02
VRATIO =   1.2000  US = 0.000220 M**2/V-SEC  FPATH =   1.0000  FRD = 1500000. V/M  RHOCGS =  5.00E+10 OHM-CM

DATA ON CARD NUMBER   6

ASNUCK( 1) = 0.00  AZIGGY( 1) = 0.00  AZNUMS( 1) =  3.0
ASNUCK( 2) = 0.10  AZIGGY( 2) = 0.25  AZNUMS( 2) =  3.0


DATA ON CARD NUMBER   7
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ENDPT( 1) =    0.100 UM   ENDPT( 2) =    0.300 UM   ENDPT( 3) =    0.500 UM   ENDPT( 4) =    0.900 UM   ENDPT( 5) =    1.300 UM
ENDPT( 6) =    1.900 UM   ENDPT( 7) =    3.100 UM   ENDPT( 8) =    3.900 UM   ENDPT( 9) =    5.100 UM   ENDPT(10) =    6.900 UM

DATA ON CARD NUMBER   8

ENDPT(11) =   10.100 UM   ENDPT(12) =   14.900 UM   ENDPT(13) =   25.100 UM   ENDPT(14) =   29.900 UM

DATA ON CARD NUMBER   9

PRCU( 1) =   0.0000 %   PRCU( 2) =   0.0330 %   PRCU( 3) =   0.2860 %   PRCU( 4) =   1.1890 %   PRCU( 5) =   2.0040 %
PRCU( 6) =   3.5240 %   PRCU( 7) =   7.0480 %   PRCU( 8) =   8.7000 %   PRCU( 9) =  10.3520 %   PRCU(10) =  12.3340 %

DATA ON CARD NUMBER  10

PRCU(11) =  15.6380 %   PRCU(12) =  20.4840 %   PRCU(13) =  32.5990 %   PRCU(14) = 100.0000 %

DATA ON CARD NUMBER  11

NUMSEC =  3    LSECT( 1) = 10  LSECT( 2) = 10  LSECT( 3) = 10

DATA ON CARD NUMBER  12

AS( 1) =  2.6460E+04 FT**2  VOS( 1) =  4.0600E+04 V  TCS( 1) =  2.7300E-01 A  WLS( 1) =  1.5720E+04 FT
ACS( 1) =  8.2500E-02 IN  BS( 1) =  5.5000E+00 IN  NWS( 1) =  1.2000E+01

DATA ON CARD NUMBER  13

BYS( 1) =  3.6250E+00 IN  VGS( 1) =  3.2724E+05 FT**3/MIN  VGASS( 1) =  4.1000E+00 FT/SEC  TEMPS( 1) =  3.1500E+02 F
PS( 1) =  1.0000E+00 ATM  VTSS( 1) =  2.2900E-05 KG/M-SEC  LINCS( 1) =  9.0000E-01 FT

DATA ON CARD NUMBER  14

AS( 2) =  2.6460E+04 FT**2  VOS( 2) =  4.2100E+04 V  TCS( 2) =  4.3300E-01 A  WLS( 2) =  1.5720E+04 FT
ACS( 2) =  8.2500E-02 IN  BS( 2) =  5.5000E+00 IN  NWS( 2) =  1.2000E+01

DATA ON CARD NUMBER  15
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SYS( 2) =  3.6250E+00 IN  VGS( 2) =  3.2724E+05 FT**3/MIN  VGASS( 2) =  4.1000E+00 FT/SEC  TEMPS( 2) =  3.1500E+02 F
PS( 2) =  1.0000E+00 ATM  VISS( 2) =  2.2900E-05 KG/M-SEC  LINCS( 2) =  9.0000E-01 FT

DATA ON CARD NUMBER  16

AS( 3) =  2.6460E+04 FT**2  VOS( 3) =  4.2450E+04 V  TCS( 3) =  5.5800E-01 A  WLS( 3) =  1.5720E+04 FT
ACS( 3) =  8.2500E-02 IN  BS( 3) =  5.5000E+00 IN  NWS( 3) =  1.2000E+01

DATA ON CARD NUMBER  17

SYS( 3) =  3.6250E+00 IN  VGS( 3) =  3.2724E+05 FT**3/MIN  VGASS( 3) =  4.1000E+00 FT/SEC  TEMPS( 3) =  3.1500E+02 F
PS( 3) =  1.0000E+00 ATM  VISS( 3) =  2.2900E-05 KG/M-SEC  LINCS( 3) =  9.0000E-01 FT
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INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


FULL-SCALE.COLD-SIDE ESP; PLANT A; SCA=243FT2/1000ACFM;J=15.9UA/FT2


CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2          APPLIED VOLTAGE =  4.060E+04 VOLTS      TOTAL CURRENT =  2.730E-01 AMPS
WIRE TO PLATE =  1.397E-01 M             CORONA WIRE RADIUS =  2.096E-03 M       CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  5.696E-05 AMP/M             CURRENT DENSITY =  1.109E-04 AMP/M2     DEPOSIT E FIELD =  5.547E+04 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M          GAS FLOW RATE =  1.548E+02 M3/SEC       GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                  PRESSURE =  1.000 ATM                   VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC    MEAN THERMAL SPEED =  5.335E+02 M/SEC   PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC          LENGTH INCR. =0.27450000 M              INPUT EFF./INCR. = 16.81


ROVRI     ERAVG       EPLT        AFID        CMCD     MMD        WEIGHT      DUST LAYER  J(PART)     J(ION)    INCR. NO.

3.1566   2.906E+05  2.0373E+05  2.1825E+12   11.1   2.29E-05   1.496E-03   5.686E-02   4.74E-07   1.10E-04       1
2.5220   2.906E+05  1.9259E+05  2.7316E+12   11.1   2.27E-05   1.189E-03   4.471E-02   6.12E-07   1.10E-04       2
2.0657   2.906E+05  1.8411E+05  3.3351E+12   11.1   2.22E-05   6.906E-04   2.606E-02   5.13E-07   1.10E-04       3
1.7689   2.906E+05  1.7833E+05  3.8945E+12   11.1   2.14E-05   3.727E-04   1.407E-02   4.05E-07   1.11E-04       4
1.5705   2.906E+05  1.7435E+05  4.3866E+12   11.1   1.98E-05   2.035E-04   7.681E-03   3.32E-07   1.11E-04       5
1.4311   2.906E+05  1.7149E+05  4.8130E+12   11.1   1.30E-05   1.182E-04   4.462E-03   2.87E-07   1.11E-04       6
1.3294   2.906E+05  1.6936E+05  5.1823E+12   11.1   8.05E-06   7.498E-05   2.830E-03   2.57E-07   1.11E-04       7
1.2532   2.906E+05  1.6774E+05  5.4972E+12   11.1   5.55E-06   5.212E-05   1.967E-03   2.37E-07   1.11E-04       8
1.1954   2.906E+05  1.6650E+05  5.7629E+12   11.1   4.15E-06   3.913E-05   1.477E-03   2.20E-07   1.11E-04       9
1.1512   2.906E+05  1.6555E+05  5.9843E+12   11.1   3.38E-06   3.110E-05   1.174E-03   2.06E-07   1.11E-04      10

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2          APPLIED VOLTAGE =  4.210E+04 VOLTS      TOTAL CURRENT =  4.330E-01 AMPS
WIRE TO PLATE =  1.397E-01 M             CORONA WIRE RADIUS =  2.096E-03 M       CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  9.031E-05 AMP/M             CURRENT DENSITY =  1.760E-04 AMP/M2     DEPOSIT E FIELD =  8.798E+04 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M          GAS FLOW RATE =  1.548E+02 M3/SEC       GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                  PRESSURE =  1.000 ATM                   VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC    MEAN THERMAL SPEED =  5.335E+02 M/SEC   PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC          LENGTH INCR. =0.27450000 M              INPUT EFF./INCR. = 16.81


ROVRI     ERAVG       EPLT        AFID        CMCD     MMD        WEIGHT      DUST LAYER  J(PART)     J(ION)    INCR. NO.

1.0766   3.014E+05  1.8116E+05  9.7875E+12   17.6   2.83E-06   2.841E-05   1.072E-03   2.18E-07   1.76E-04      11
1.0590   3.014E+05  1.8061E+05  9.9504E+12   17.6   2.46E-06   2.387E-05   9.009E-04   2.07E-07   1.76E-04      12
1.0455   3.014E+05  1.8019E+05  1.0079E+13   17.6   2.33E-06   2.038E-05   7.693E-04   1.96E-07   1.76E-04      13
1.0350   3.014E+05  1.7986E+05  1.0181E+13   17.6   2.22E-06   1.760E-05   6.644E-04   1.85E-07   1.76E-04      14
1.0270   3.014E+05  1.7986E+05  1.0260E+13   17.6   2.13E-06   1.535E-05   5.795E-04   1.74E-07   1.76E-04      15
1.0209   3.014E+05  1.7986E+05  1.0322E+13   17.6   2.05E-06   1.347E-05   5.084E-04   1.63E-07   1.76E-04      16
1.0161   3.014E+05  1.7986E+05  1.0370E+13   17.6   1.98E-06   1.187E-05   4.481E-04   1.54E-07   1.76E-04      17
1.0124   3.014E+05  1.7986E+05  1.0408E+13   17.6   1.91E-06   1.051E-05   3.965E-04   1.44E-07   1.76E-04      18
1.0096   3.014E+05  1.7986E+05  1.0437E+13   17.6   1.85E-06   9.329E-06   3.521E-04   1.35E-07   1.76E-04      19
1.0074   3.014E+05  1.7986E+05  1.0460E+13   17.6   1.79E-06   8.308E-06   3.136E-04   1.27E-07   1.76E-04      20

CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  2.7450 M
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COLLECTION AREA =  2.461E+03 M2         APPLIED VOLTAGE =  4.245E+04 VOLTS        TOTAL CURRENT =  5.580E-01 AMPS
WIRE TO PLATE =  1.397E-01 M            CORONA WIRE RADIUS =  2.096E-03 M         CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  1.164E-04 AMP/M            CURRENT DENSITY =  2.268E-04 AMP/M2       DEPOSIT E FIELD =  1.134E+05 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M         GAS FLOW RATE =  1.548E+02 M3/SEC         GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                 PRESSURE =   1.000 ATM                    VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  5.335E+02 M/SEC     PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC         LENGTH INCR. =0.27450000 M                INPUT EFF./INCR. = 16.81

ROVRI     ERAVG        EPLT        AFID        CMCD      MMD          WEIGHT     DUST LAYER   J(PART)       J(ION)    INCR. NO.

1.0045   3.039E+05  1.8870E+05  1.3407E+13    22.7    1.73E-06    7.779E-06   2.936E-04   1.25E-07    2.27E-04       21
1.0035   3.039E+05  1.8870E+05  1.3421E+13    22.7    1.67E-06    6.934E-06   2.617E-04   1.17E-07    2.27E-04       22
1.0027   3.039E+05  1.8870E+05  1.3432E+13    22.7    1.61E-06    6.193E-06   2.337E-04   1.10E-07    2.27E-04       23
1.0021   3.039E+05  1.8870E+05  1.3440E+13    22.7    1.56E-06    5.538E-06   2.090E-04   1.03E-07    2.27E-04       24
1.0016   3.039E+05  1.8870E+05  1.3446E+13    22.7    1.51E-06    4.962E-06   1.873E-04   9.64E-08    2.27E-04       25
1.0012   3.039E+05  1.8870E+05  1.3451E+13    22.7    1.46E-06    4.449E-06   1.679E-04   9.01E-08    2.27E-04       26
1.0010   3.039E+05  1.8870E+05  1.3455E+13    22.7    1.42E-06    3.992E-06   1.507E-04   8.42E-08    2.27E-04       27
1.0007   3.039E+05  1.8870E+05  1.3458E+13    22.7    1.38E-06    3.590E-06   1.355E-04   7.87E-08    2.27E-04       28
1.0006   3.039E+05  1.8870E+05  1.3460E+13    22.7    1.34E-06    3.231E-06   1.220E-04   7.34E-08    2.27E-04       29
1.0004   3.039E+05  1.8870E+05  1.3462E+13    22.7    1.30E-06    2.914E-06   1.100E-04   6.86E-08    2.27E-04       30

EST. EFFICIENCY = 99.60     UNCORRECTED COMPUTED EFFICIENCY = 99.32

INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


FULL-SCALE,COLD-SIDE ESP; PLANT A; SCA=243FT2/1000ACFM;J=15.9UA/FT2

CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2         APPLIED VOLTAGE =  4.060E+04 VOLTS        TOTAL CURRENT =  2.730E-01 AMPS
WIRE TO PLATE =  1.397E-01 M            CORONA WIRE RADIUS =  2.096E-03 M         CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  5.694E-05 AMP/M            CURRENT DENSITY =  1.109E-04 AMP/M2       DEPOSIT E FIELD =  5.547E+04 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M         GAS FLOW RATE =  1.548E+02 M3/SEC         GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                 PRESSURE =   1.000 ATM                    VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  5.335E+02 M/SEC     PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC         LENGTH INCR. =0.27450000 M                INPUT EFF./INCR. = 15.34

ROVRI     ERAVG        EPLT        AFID        CMCD      MMD          WEIGHT     DUST LAYER   J(PART)       J(ION)    INCR. NO.

2.9685   2.906E+05  2.0050E+05  2.3207E+12    11.1    2.29E-05    1.517E-03   5.727E-02   4.98E-07    1.10E-04        1
2.8100   2.906E+05  1.9055E+05  2.8586E+12    11.1    2.27E-05    1.182E-03   4.460E-02   6.24E-07    1.10E-04        2
2.0041   2.906E+05  1.8293E+05  3.4375E+12    11.1    2.22E-05    6.838E-04   2.581E-02   5.17E-07    1.10E-04        3
1.7374   2.906E+05  1.7771E+05  3.9652E+12    11.1    2.14E-05    3.679E-04   1.389E-02   4.06E-07    1.11E-04        4
1.5569   2.906E+05  1.7407E+05  4.4250E+12    11.1    1.97E-05    2.008E-04   7.580E-03   3.33E-07    1.11E-04        5
1.4283   2.906E+05  1.7143E+05  4.8234E+12    11.1    1.28E-05    1.168E-04   4.407E-03   2.87E-07    1.11E-04        6
1.3329   2.906E+05  1.6944E+05  5.1684E+12    11.1    7.96E-06    7.421E-05   2.801E-03   2.58E-07    1.11E-04        7
1.2605   2.906E+05  1.6789E+05  5.4655E+12    11.1    5.49E-06    5.168E-05   1.950E-03   2.37E-07    1.11E-04        8
1.2046   2.906E+05  1.6670E+05  5.7192E+12    11.1    4.12E-06    3.886E-05   1.467E-03   2.20E-07    1.11E-04        9
1.1610   2.906E+05  1.6577E+05  5.9336E+12    11.1    3.36E-06    3.092E-05   1.167E-03   2.06E-07    1.11E-04       10

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2         APPLIED VOLTAGE =  4.210E+04 VOLTS        TOTAL CURRENT =  4.330E-01 AMPS
WIRE TO PLATE =  1.397E-01 M            CORONA WIRE RADIUS =  2.096E-03 M         CORONA WIRE LENGTH =  4.795E+03 M
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CURRENT/M =  9.031E-05 AMP/M           CURRENT DENSITY =  1.760E-04 AMP/M2     DEPOSIT E FIELD =  8.798E+04 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M        GAS FLOW RATE =  1.548E+02 M3/SEC       GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                PRESSURE =   1.000 ATM                  VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  5.335E+02 M/SEC   PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC        LENGTH INCR. =0.27450000 M              INPUT EFF./INCR. = 15.34

ROVRI     ERAVG       EPLT        AFID         CMCD     MMD         WEIGHT      DUST LAYER   J(PART)      J(ION)     INCR. NO.

1.0830   3.014E+05  1.8135E+05  9.7295E+12    17.6    2.82E-06    2.825E-05    1.066E-03    2.18E-07     1.76E-04      11
1.0651   3.014E+05  1.8080E+05  9.8937E+12    17.6    2.45E-06    2.375E-05    8.963E-04    2.07E-07     1.76E-04      12
1.0510   3.014E+05  1.8036E+05  1.0026E+13    17.6    2.32E-06    2.028E-05    7.655E-04    1.95E-07     1.76E-04      13
1.0400   3.014E+05  1.8002E+05  1.0132E+13    17.6    2.22E-06    1.752E-05    6.612E-04    1.84E-07     1.76E-04      14
1.0314   3.014E+05  1.8002E+05  1.0217E+13    17.6    2.13E-06    1.528E-05    5.768E-04    1.73E-07     1.76E-04      15
1.0247   3.014E+05  1.8002E+05  1.0284E+13    17.6    2.05E-06    1.341E-05    5.061E-04    1.63E-07     1.76E-04      16
1.0194   3.014E+05  1.8002E+05  1.0337E+13    17.6    1.97E-06    1.182E-05    4.461E-04    1.53E-07     1.76E-04      17
1.0152   3.014E+05  1.8002E+05  1.0379E+13    17.6    1.91E-06    1.046E-05    3.948E-04    1.44E-07     1.76E-04      18
1.0120   3.014E+05  1.8002E+05  1.0413E+13    17.6    1.85E-06    9.288E-06    3.505E-04    1.35E-07     1.76E-04      19
1.0094   3.014E+05  1.8002E+05  1.0439E+13    17.6    1.79E-06    8.273E-06    3.122E-04    1.26E-07     1.76E-04      20

CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2        APPLIED VOLTAGE =  4.245E+04 VOLTS      TOTAL CURRENT =  5.580E-01 AMPS
WIRE TO PLATE =  1.397E-01 M           CORONA WIRE RADIUS =  2.096E-03 M       CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  1.164E-04 AMP/M           CURRENT DENSITY =  2.268E-04 AMP/M2     DEPOSIT E FIELD =  1.134E+05 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M        GAS FLOW RATE =  1.548E+02 M3/SEC       GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                PRESSURE =   1.000 ATM                  VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  5.335E+02 M/SEC   PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC        LENGTH INCR. =0.27450000 M              INPUT EFF./INCR. = 15.34

ROVRI     ERAVG       EPLT        AFID         CMCD     MMD         WEIGHT      DUST LAYER   J(PART)      J(ION)     INCR. NO.

1.0058   3.039E+05  1.8875E+05  1.3390E+13    22.7    1.73E-06    7.742E-06    2.922E-04    1.25E-07     2.27E-04      21
1.0046   3.039E+05  1.8875E+05  1.3406E+13    22.7    1.67E-06    6.902E-06    2.605E-04    1.17E-07     2.27E-04      22
1.0036   3.039E+05  1.8875E+05  1.3419E+13    22.7    1.61E-06    6.165E-06    2.327E-04    1.10E-07     2.27E-04      23
1.0028   3.039E+05  1.8875E+05  1.3430E+13    22.7    1.56E-06    5.513E-06    2.081E-04    1.03E-07     2.27E-04      24
1.0022   3.039E+05  1.8875E+05  1.3438E+13    22.7    1.51E-06    4.940E-06    1.864E-04    9.61E-08     2.27E-04      25
1.0017   3.039E+05  1.8875E+05  1.3444E+13    22.7    1.46E-06    4.429E-06    1.672E-04    8.99E-08     2.27E-04      26
1.0014   3.039E+05  1.8875E+05  1.3449E+13    22.7    1.42E-06    3.975E-06    1.500E-04    8.39E-08     2.27E-04      27
1.0011   3.039E+05  1.8875E+05  1.3453E+13    22.7    1.37E-06    3.574E-06    1.349E-04    7.84E-08     2.27E-04      28
1.0008   3.039E+05  1.8875E+05  1.3456E+13    22.7    1.33E-06    3.218E-06    1.214E-04    7.32E-08     2.27E-04      29
1.0007   3.039E+05  1.8875E+05  1.3459E+13    22.7    1.30E-06    2.902E-06    1.095E-04    6.84E-08     2.27E-04      30
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CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHARGN OR CHGSUM

SRI THEORY USED FOR PARTICLE CHARGING

INCREMENT NO.     Q/QSATF FOR INDICATED PARTICLE SIZES

     0.2000E-06   0.4000E-06   0.7000E-06   0.1100E-05   0.1600E-05   0.2500E-05   0.3500E-05   0.4500E-05
  1   0.5314       0.5228       0.4934       0.4720       0.4586       0.4470       0.4409       0.4374
  2   0.7618       0.7543       0.7124       0.6797       0.6579       0.6388       0.6286       0.6231
  3   0.9210       0.9215       0.8587       0.8079       0.7749       0.7468       0.7324       0.7251
  4   1.0579       1.0642       0.9817       0.9027       0.8545       0.8156       0.7965       0.7873
  5   1.1668       1.1669       1.0731       0.9832       0.9164       0.8641       0.8397       0.8282
  6   1.2550       1.2460       1.1384       1.0406       0.9688       0.9017       0.8709       0.8570
  7   1.3295       1.3100       1.1890       1.0828       1.0068       0.9335       0.8951       0.8784
  8   1.3936       1.3634       1.2301       1.1161       1.0357       0.9611       0.9150       0.8950
  9   1.4494       1.4091       1.2646       1.1434       1.0589       0.9819       0.9324       0.9085
 10   1.4988       1.4488       1.2941       1.1665       1.0783       0.9986       0.9484       0.9199
 11   1.5703       1.5080       1.3399       1.2039       1.1110       1.0289       0.9749       0.9431
 12   1.6298       1.5562       1.3763       1.2329       1.1357       1.0498       0.9970       0.9599
 13   1.6806       1.5968       1.4065       1.2566       1.1554       1.0664       1.0133       0.9736
 14   1.7249       1.6317       1.4322       1.2765       1.1719       1.0799       1.0259       0.9858
 15   1.7642       1.6624       1.4546       1.2937       1.1859       1.0912       1.0362       0.9969
 16   1.7994       1.6896       1.4743       1.3088       1.1981       1.1009       1.0448       1.0059
 17   1.8312       1.7141       1.4920       1.3222       1.2090       1.1094       1.0522       1.0134
 18   1.8602       1.7364       1.5080       1.3342       1.2186       1.1170       1.0588       1.0199
 19   1.8869       1.7567       1.5225       1.3452       1.2274       1.1238       1.0646       1.0254
 20   1.9116       1.7755       1.5359       1.3552       1.2354       1.1299       1.0698       1.0304
 21   1.9411       1.7981       1.5522       1.3676       1.2455       1.1379       1.0766       1.0369
 22   1.9681       1.8187       1.5670       1.3789       1.2545       1.1450       1.0827       1.0426
 23   1.9930       1.8376       1.5806       1.3891       1.2627       1.1513       1.0881       1.0476
 24   2.0161       1.8551       1.5930       1.3985       1.2702       1.1571       1.0881       1.0476
 25   2.0376       1.8714       1.6046       1.4071       1.2771       1.1625       1.0881       1.0476
 26   2.0578       1.8865       1.6154       1.4152       1.2835       1.1625       1.0881       1.0476
 27   2.0767       1.9008       1.6254       1.4227       1.2835       1.1625       1.0881       1.0476
 28   2.0945       1.9141       1.6349       1.4298       1.2835       1.1625       1.0881       1.0476
 29   2.1114       1.9268       1.6438       1.4298       1.2835       1.1625       1.0881       1.0476
 30   2.1274       1.9387       1.6522       1.4298       1.2835       1.1625       1.0881       1.0476

     0.6000E-05   0.8500E-05   0.1250E-04   0.2000E-04   0.2750E-04
  1   0.4345       0.4323       0.4310       0.4305       0.4304
  2   0.6189       0.6163       0.6152       0.6149       0.6149
  3   0.7200       0.7172       0.7164       0.7162       0.7162
  4   0.7812       0.7783       0.7776       0.7775       0.7774
  5   0.8211       0.8179       0.8172       0.8171       0.8171
  6   0.8486       0.8450       0.8443       0.8442       0.8442
  7   0.8685       0.8644       0.8636       0.8635       0.8635
  8   0.8834       0.8788       0.8779       0.8779       0.8779
  9   0.8951       0.8898       0.8888       0.8888       0.8888
 10   0.9044       0.8984       0.8974       0.8973       0.8973
 11   0.9271       0.9211       0.9202       0.9201       0.9201
 12   0.9418       0.9353       0.9343       0.9342       0.9342
 13   0.9523       0.9450       0.9439       0.9438       0.9438
 14   0.9604       0.9521       0.9508       0.9507       0.9507
 15   0.9670       0.9575       0.9560       0.9559       0.9559
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16	0.9727	0.9617	0.9601	0.9600	0.9600
17	0.9777	0.9617	0.9601	0.9600	0.9600
18	0.9823	0.9617	0.9601	0.9600	0.9600
19	0.9823	0.9617	0.9601	0.9600	0.9600
20	0.9823	0.9617	0.9601	0.9600	0.9600
21	0.9883	0.9681	0.9663	0.9662	0.9662
22	0.9883	0.9681	0.9663	0.9662	0.9662
23	0.9883	0.9681	0.9663	0.9662	0.9662
24	0.9883	0.9681	0.9663	0.9662	0.9662
25	0.9883	0.9681	0.9663	0.9662	0.9662
26	0.9883	0.9681	0.9663	0.9662	0.9662
27	0.9883	0.9681	0.9663	0.9662	0.9662
28	0.9883	0.9681	0.9663	0.9662	0.9662
29	0.9883	0.9681	0.9663	0.9662	0.9662
30	0.9883	0.9681	0.9663	0.9662	0.9662

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CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT

INCREMENT       CHARGE FOR INDICATED PARTICLE SIZES

         0.2000E-06    0.4000E-06    0.7000E-06    0.1100E-05    0.1600E-05    0.2500E-05    0.3500E-05    0.4500E-05
  1    0.94670E-18   0.28569E-17   0.75930E-17   0.17430E-16   0.35425E-16   0.83762E-16   0.16153E-15   0.26467E-15
  2    0.13570E-17   0.41220E-17   0.10963E-16   0.25100E-16   0.50824E-16   0.11970E-15   0.23032E-15   0.37703E-15
  3    0.16408E-17   0.50362E-17   0.13214E-16   0.29835E-16   0.59861E-16   0.13994E-15   0.26836E-15   0.43872E-15
  4    0.18846E-17   0.58155E-17   0.15108E-16   0.33337E-16   0.66010E-16   0.15283E-15   0.29185E-15   0.47634E-15
  5    0.20778E-17   0.63772E-17   0.16513E-16   0.36308E-16   0.70794E-16   0.16192E-15   0.30765E-15   0.50113E-15
  6    0.22357E-17   0.68094E-17   0.17518E-16   0.38428E-16   0.74840E-16   0.16897E-15   0.31910E-15   0.51853E-15
  7    0.23685E-17   0.71589E-17   0.18297E-16   0.39988E-16   0.77779E-16   0.17492E-15   0.32796E-15   0.53145E-15
  8    0.24826E-17   0.74508E-17   0.18929E-16   0.41216E-16   0.80013E-16   0.18010E-15   0.33527E-15   0.54150E-15
  9    0.25821E-17   0.77005E-17   0.19460E-16   0.42225E-16   0.81806E-16   0.18399E-15   0.34164E-15   0.54968E-15
 10    0.26700E-17   0.79178E-17   0.19915E-16   0.43078E-16   0.83297E-16   0.18712E-15   0.34749E-15   0.55660E-15
 11    0.27974E-17   0.82412E-17   0.20619E-16   0.44459E-16   0.85825E-16   0.19272E-15   0.35719E-15   0.57062E-15
 12    0.29033E-17   0.85046E-17   0.21179E-16   0.45531E-16   0.87732E-16   0.19672E-15   0.36531E-15   0.58079E-15
 13    0.29939E-17   0.87262E-17   0.21644E-16   0.46404E-16   0.89260E-16   0.19983E-15   0.37126E-15   0.58904E-15
 14    0.30729E-17   0.89172E-17   0.22040E-16   0.47140E-16   0.90530E-16   0.20235E-15   0.37588E-15   0.59643E-15
 15    0.31428E-17   0.90846E-17   0.22384E-16   0.47775E-16   0.91614E-16   0.20447E-15   0.37965E-15   0.60317E-15
 16    0.32055E-17   0.92336E-17   0.22688E-16   0.48331E-16   0.92559E-16   0.20629E-15   0.38281E-15   0.60864E-15
 17    0.32622E-17   0.93676E-17   0.22960E-16   0.48827E-16   0.93395E-16   0.20789E-15   0.38554E-15   0.61318E-15
 18    0.33139E-17   0.94892E-17   0.23206E-16   0.49272E-16   0.94143E-16   0.20931E-15   0.38793E-15   0.61706E-15
 19    0.33614E-17   0.96004E-17   0.23430E-16   0.49677E-16   0.94820E-16   0.21058E-15   0.39006E-15   0.62044E-15
 20    0.34054E-17   0.97029E-17   0.23635E-16   0.50047E-16   0.95438E-16   0.21173E-15   0.39197E-15   0.62342E-15
 21    0.34580E-17   0.98265E-17   0.23886E-16   0.50506E-16   0.96214E-16   0.21322E-15   0.39448E-15   0.62739E-15
 22    0.35061E-17   0.99391E-17   0.24114E-16   0.50920E-16   0.96912E-16   0.21455E-15   0.39669E-15   0.63083E-15
 23    0.35505E-17   0.10043E-16   0.24323E-16   0.51297E-16   0.97545E-16   0.21574E-15   0.39867E-15   0.63385E-15
 24    0.35916E-17   0.10138E-16   0.24515E-16   0.51644E-16   0.98124E-16   0.21683E-15   0.39867E-15   0.63385E-15
 25    0.36299E-17   0.10227E-16   0.24692E-16   0.51964E-16   0.98658E-16   0.21783E-15   0.39867E-15   0.63385E-15
 26    0.36658E-17   0.10310E-16   0.24858E-16   0.52262E-16   0.99152E-16   0.21783E-15   0.39867E-15   0.63385E-15
 27    0.36995E-17   0.10387E-16   0.25013E-16   0.52539E-16   0.99152E-16   0.21783E-15   0.39867E-15   0.63385E-15
 28    0.37313E-17   0.10461E-16   0.25159E-16   0.52800E-16   0.99152E-16   0.21783E-15   0.39867E-15   0.63385E-15
 29    0.37614E-17   0.10530E-16   0.25296E-16   0.52800E-16   0.99152E-16   0.21783E-15   0.39867E-15   0.63385E-15
 30    0.37900E-17   0.10595E-16   0.25426E-16   0.52800E-16   0.99152E-16   0.21783E-15   0.39867E-15   0.63385E-15

         0.6000E-05    0.8500E-05    0.1250E-04    0.2000E-04    0.2750E-04
  1    0.46706E-15   0.93203E-15   0.20091E-14   0.51358E-14   0.97067E-14
  2    0.66524E-15   0.13287E-14   0.28676E-14   0.73361E-14   0.13868E-13
  3    0.77385E-15   0.15463E-14   0.33392E-14   0.85445E-14   0.16153E-13
  4    0.83967E-15   0.16780E-14   0.36243E-14   0.92750E-14   0.17534E-13
  5    0.88251E-15   0.17633E-14   0.38089E-14   0.97479E-14   0.18428E-13
  6    0.91206E-15   0.18217E-14   0.39351E-14   0.10071E-13   0.19039E-13
  7    0.93344E-15   0.18635E-14   0.40253E-14   0.10302E-13   0.19476E-13
  8    0.94953E-15   0.18946E-14   0.40921E-14   0.10473E-13   0.19799E-13
  9    0.96205E-15   0.19183E-14   0.41430E-14   0.10603E-13   0.20045E-13
 10    0.97209E-15   0.19369E-14   0.41827E-14   0.10705E-13   0.20237E-13
 11    0.99642E-15   0.19860E-14   0.42890E-14   0.10977E-13   0.20752E-13
 12    0.10122E-14   0.20165E-14   0.43548E-14   0.11145E-13   0.21070E-13
 13    0.10236E-14   0.20374E-14   0.43995E-14   0.11260E-13   0.21286E-13
 14    0.10323E-14   0.20527E-14   0.44317E-14   0.11342E-13   0.21442E-13
 15    0.10394E-14   0.20643E-14   0.44560E-14   0.11404E-13   0.21559E-13
 16    0.10454E-14   0.20735E-14   0.44749E-14   0.11453E-13   0.21651E-13
 17    0.10508E-14   0.20735E-14   0.44749E-14   0.11453E-13   0.21651E-13
 18    0.10558E-14   0.20735E-14   0.44749E-14   0.11453E-13   0.21651E-13
 19    0.10558E-14   0.20735E-14   0.44749E-14   0.11453E-13   0.21651E-13
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20   0.10558E-14   0.20735E-14   0.44749E-14   0.11453E-13   0.21651E-13
21   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
22   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
23   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
24   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
25   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
26   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
27   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
28   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
29   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
30   0.10623E-14   0.20871E-14   0.45040E-14   0.11527E-13   0.21791E-13
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PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  1 OF CORRECTION PARAMETERS

  SIZE      CCF  INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W     COR. P
2.000E-07  2.123  0.033   0.7203       0.4526     95.2710      6.398   4.7290   95.0353     6.296      4.9647
4.000E-07  1.530  0.253   7.4214       4.5547     93.6452      5.778   6.3548   93.4839     5.726      6.5161
7.000E-07  1.297  0.903  23.1836      14.5134     94.4380      6.058   5.5620   94.1826     5.964      5.8174
1.100E-06  1.188  0.815  15.2173      10.2466     95.9550      6.726   4.0450   95.4494     6.479      4.5506
1.600E-06  1.130  1.520  19.2314      13.8084     97.2590      7.541   2.7410   96.7119     7.160      3.2881
2.500E-06  1.083  3.524  23.2589      19.1755     98.5701      8.906   1.4299   98.0305     8.234      1.9695
3.500E-06  1.059  1.652   6.0486       6.9775     99.2068     10.141   0.7932   98.4713     8.766      1.5287
4.500E-06  1.046  1.652   3.7049       6.6554     99.5141     11.169   0.4859   98.5418     8.865      1.4582
6.000E-06  1.035  1.982   1.0448       5.8876     99.8858     14.205   0.1142   98.9248     9.504      1.0752
8.500E-06  1.024  3.304   0.1301       6.2833     99.9915     19.645   0.0085   99.3117    10.439      0.6883
1.250E-05  1.017  4.846   0.0022       5.0000     99.9999     32.033   0.0001   99.6265    11.721      0.3735
2.000E-05  1.010 12.115   0.0055       4.0677     99.9999     50.924   0.0001   99.8785    14.075      0.1215
2.750E-05  1.008 67.401   0.0309       2.3772     99.9999     69.820   0.0001   99.9872    18.799      0.0128

   EFFICIENCY - STATED = 99.32     COMPUTED = 99.3273     CONVERGENCE OBTAINED


   ADJUSTED NO-RAP EFF. =  99.7834
   MMD OF INLET SIZE DISTRIBUTION =  4.465E+01
   SIGMAP OF INLET SIZE DISTRIBUTION =  5.122E+00
   LOG-NORMAL GOODNESS OF FIT =  0.984
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.334E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.891E+00
   LOG-NORMAL GOODNESS OF FIT =  0.997
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 12.862


   SIGMAG=    0.000  WITH  0.000 SNEAKAGE OVER    3.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  99.6381
   CORRECTED MMD OF EFFLUENT =  2.667E+00
   CORRECTED SIGMAP OF EFFLUENT =  2.796E+00
   LOG-NORMAL GOODNESS OF FIT =  0.988
   CORRECTED PRECIPITATION RATE PARAMETER =   11.79
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP             RAPPING PUFF        NO-RAP+RAP PUFF        RAPPING PUFF       PARTICLE
MIG. VEL.(CM/SEC)    EFFICIENCY(%)     DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 2.633E+00            7.151E+01           2.324E-01          1.158E-02           2.440E-01           5.350E-02        2.000E-07
 2.739E+00            7.291E+01           5.149E+00          1.306E-01           5.280E+00           2.806E-01        4.000E-07
 3.274E+00            7.902E+01           1.398E+01          6.418E-01           1.462E+01           1.586E+00        7.000E-07
 4.081E+00            8.572E+01           1.467E+01          1.833E+00           1.650E+01           2.834E+00        1.100E-06
 5.116E+00            9.129E+01           1.796E+01          3.585E+00           2.155E+01           5.720E+00        1.600E-06
 7.013E+00            9.647E+01           1.684E+01          6.355E+00           2.319E+01           1.308E+01        2.500E-06
 9.095E+00            9.869E+01           9.338E+00          8.659E+00           1.800E+01           8.358E+00        3.500E-06
 1.117E+01            9.951E+01           4.895E+00          9.796E+00           1.469E+01           1.105E+01        4.500E-06
 1.420E+01            9.989E+01           1.225E+00          1.031E+01           1.153E+01           1.310E+01        6.000E-06
 1.965E+01            9.999E+01           1.210E-01          9.644E+00           9.765E+00           1.545E+01        8.500E-06
 3.203E+01            1.000E+02           2.022E-03          7.614E+00           7.616E+00           1.245E+01        1.250E-05
 5.092E+01            1.000E+02           3.769E-03          4.619E+00           4.622E+00           1.013E+01        2.000E-05
 6.982E+01            1.000E+02           6.250E-02          8.044E+00           8.107E+00           5.918E+00        2.750E-05
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                         SUMMARY TABLE OF ESP OPERATING
                          PARAMETERS AND PERFORMANCE


                              DATA SET NUMBER   1

ESP PERFORMANCE:     EFFICIENCY =  99.6381 %     SCA =  4.769E+01 M**2/(M**3/SEC)

ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.172E+04 V

                           AVG. CURRENT DENSITY =   17.12 NA/CM**2

                           RESISTIVITY =  5.000E+10 OHM-CM

SIZE DISTRIBUTIONS:     INLET MMD =  4.465E+01 UM     INLET SIGMAP =  5.122E+00

                        OUTLET MMD =  2.667E+00 UM     OUTLET SIGMAP =  2.796E+00

NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.00 /SECTION     GAS VELOCITY SIGMAG = 0.00

                         RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00
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PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO.  2 OF CORRFCTION PARAMETERS
  SIZE       CCF   INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.  COR. W     COR. P
2.000E-07  2.123   0.033   0.4412       0.3266       91.8499      5.257    8.1501   91.4343    5.152     8.5657
4.000E-07  1.530   0.253   4.3398       3.1396       89.5441      4.734   10.4559   89.2598    4.678    10.7402
7.000E-07  1.297   0.903  14.3436      10.5717       90.3176      4.895    9.6824   89.8674    4.800    10.1326
1.100E-06  1.188   0.815  10.5249       8.2518       92.1282      5.330    7.8718   91.2369    5.105     8.7631
1.600E-06  1.130   1.520  15.4375      12.5663       93.8092      5.833    6.1908   92.8447    5.530     7.1553
2.500E-06  1.083   3.524  24.9331      21.4337       95.6873      6.591    4.3127   94.7359    6.173     5.2641
3.500E-06  1.059   1.652   9.0291       8.8341       96.6685      7.132    3.3315   95.3717    6.443     4.6283
4.500E-06  1.046   1.652   7.8160       8.7766       97.1160      7.435    2.8840   95.4019    6.457     4.5981
6.000E-06  1.035   1.982   5.2527       7.5790       98.3846      8.650    1.6154   96.6904    7.146     3.3096
8.500E-06  1.024   3.304   4.6493       7.8495       99.1422      9.977    0.8578   97.9438    8.144     2.0562
1.250E-05  1.017   4.846   2.8772       5.7125       99.6381     11.787    0.3619   98.9798    9.614     1.0202
2.000E-05  1.010  12.115   0.2936       3.2058       99.9852     18.493    0.0148   99.7710   12.746     0.2290
2.750E-05  1.008  67.401   0.0620       1.7527      099.9994     69.820    0.0006   99.9775   17.610     0.0225
    EFFICIENCY = STATED = 99.32        COMPUTED = 99.3273        CONVERGENCE OBTAINED

    ADJUSTED NO-RAP EFF. =  99.3904
    MMD OF INLET SIZE DISTRIBUTION =  4.465E+01
    SIGMAP OF INLET SIZE DISTRIBUTION =  5.122E+00
    LOG-NORMAL GOODNESS OF FIT =  0.984
    MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.086E+00
    SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.253E+00
    LOG-NORMAL GOODNESS OF FIT =  0.997
    PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 10.694

    SIGMAG=    0.250  WITH  0.100 SNEAKAGE OVER    3.000  STAGES
    NTEMP = 1
    RMMD =  6.00
    RSIGMA = 2.50
    CORR. EFF. =  99.1345
    CORRECTED MMD OF EFFLUENT =  2.927E+00
    CORRECTED SIGMAP OF EFFLUENT =  2.596E+00
    LOG-NORMAL GOODNESS OF FIT =  0.996
    CORRECTED PRECIPITATION RATE PARAMETER =     9.96
```

```
UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP            RAPPING PUFF      NO-RAP+RAP PUFF     RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)   EFFICIENCY(%)     DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 2.633E+00            7.151E+01          4.005E-01          2.042E-02          4.209E-01          5.350E-02        2.000E-07
 2.739E+00            7.291E+01          8.472E+00          2.303E-01          8.702E+00          2.806E-01        4.000E-07
 3.274E+00            7.902E+01          2.433E+01          1.132E+00          2.547E+01          1.586E+00        7.000E-07
 4.081E+00            8.572E+01          2.854E+01          3.232E+00          3.177E+01          2.834E+00        1.100E-06
 5.116E+00            9.129E+01          4.057E+01          6.320E+00          4.689E+01          5.720E+00        1.600E-06
 7.013E+00            9.647E+01          5.079E+01          1.120E+01          6.199E+01          1.308E+01        2.500E-06
 9.095E+00            9.869E+01          3.922E+01          1.527E+01          5.448E+01          8.358E+00        3.500E-06
 1.117E+01            9.951E+01          2.905E+01          1.727E+01          4.632E+01          1.105E+01        4.500E-06
 1.420E+01            9.989E+01          1.733E+01          1.817E+01          3.550E+01          1.310E+01        6.000E-06
 1.965E+01            9.999E+01          1.217E+01          1.700E+01          2.917E+01          1.545E+01        8.500E-06
 3.203E+01            1.000E+02          7.379E+00          1.342E+01          2.080E+01          1.245E+01        1.250E-05
 5.092E+01            1.000E+02          5.615E-01          8.142E+00          8.704E+00          1.013E+01        2.000E-05
 6.982E+01            1.000E+02          3.533E-01          1.418E+01          1.454E+01          5.918E+00        2.750E-05
```

```
*******************************************************************************************
*                                                                                         *
*                          SUMMARY TABLE OF ESP OPERATING                                 *
*                           PARAMETERS AND PERFORMANCE                                    *
*                                                                                         *
*                                                                                         *
*                                DATA SET NUMBER   2                                      *
*                                                                                         *
*   ESP PERFORMANCE:     EFFICIENCY =  99.1345 %     SCA =  4.769E+01 M**2/(M**3/SEC)     *
*                                                                                         *
*   ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.172E+04 V                        *
*                              AVG. CURRENT DENSITY =   17.12 NA/CM**2                    *
*                              RESISTIVITY =  5.000E+10 OHM-CM                            *
*                                                                                         *
*   SIZE DISTRIBUTIONS:     INLET MMD =  4.465E+01 UM     INLET SIGMAP =  5.172E+00       *
*                           OUTLET MMD =  2.927E+00 UM     OUTLET SIGMAP =  2.596E+00     *
*                                                                                         *
*   NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.10 /SECTION     GAS VELOCITY SIGMAG = 0.25
*                            RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00  *
*                                                                                         *
*******************************************************************************************
STOP  011111
```

APPENDIX N

OUTPUT DATA FOR EXAMPLE 4 (REVISION 1)

```
*************************************
*                                   *
*         E.P.A. ESP MODEL          *
*                                   *
*    I.E.R.L.-R.T.P. AND SO.R.I.    *
*                                   *
*     REVISION I,JAN. 1, 1978       *
*                                   *
*************************************

PRINTOUT OF INPUT DATA FOR DATA SET NUMBER  1


DATA ON CARD NUMBER   1

NENDPT = 14   NDATA =  1

DATA ON CARD NUMBER   2

FULL-SCALE,COLD-SIDE ESP; PLANT A; SCA=243FT2/1000ACFM;J=15.9UA/FT2

DATA ON CARD NUMBER   3

NEST =  1  NDIST =  1  NVI =  1  NX = 10  NY = 10  NITER =  3  NCALC =  0  NRAPD =  1  NEFF =  1  NTEMP =  1  NONID =  2

DATA ON CARD NUMBER   4

NN = 10  NUMINC = 20

DATA ON CARD NUMBER   5

DL =  1.96600 GRN/ACF  PL =  27.0000 FT  ETAO = 99.60000 %  DD =  2270,00 KG/M**3  EPS =  1.000E+02
VRATIO =   1,2000  US = 0.000220 M**2/V-SEC  FPATH =   1,0000  ERD = 1500000. V/M  RHOCGS =  5,00E+10 OHM-CM

DATA ON CARD NUMBER   6

ASNUCK( 1) = 0,00  AZIGGY( 1) = 0,00  AZNUMB( 1) =  3.0
ASNUCK( 2) = 0,10  AZIGGY( 2) = 0,25  AZNUMB( 2) =  3.0

DATA ON CARD NUMBER   7
```

```
ENDPT( 1) =    0.100 UM   ENDPT( 2) =    0.300 UM   ENDPT( 3) =    0.500 UM   ENDPT( 4) =    0.900 UM   ENDPT( 5) =    1.300 UM
ENDPT( 6) =    1.900 UM   ENDPT( 7) =    3.100 UM   ENDPT( 8) =    3.900 UM   ENDPT( 9) =    5.100 UM   ENDPT(10) =    6.900 UM


DATA ON CARD NUMBER   8

ENDPT(11) =   10.100 UM   ENDPT(12) =   14.900 UM   ENDPT(13) =   25.100 UM   ENDPT(14) =   29.900 UM

DATA ON CARD NUMBER   9

PRCU( 1) =   0.0000 %   PRCU( 2) =   0.0330 %   PRCU( 3) =   0.2860 %   PRCU( 4) =   1.1890 %   PRCU( 5) =   2.0040 %
PRCU( 6) =   3.5240 %   PRCU( 7) =   7.0480 %   PRCU( 8) =   8.7000 %   PRCU( 9) =  10.3520 %   PRCU(10) =  12.3340 %


DATA ON CARD NUMBER  10

PRCU(11) =  15.6380 %   PRCU(12) =  20.4840 %   PRCU(13) =  32.5990 %   PRCU(14) = 100.0000 %

DATA ON CARD NUMBER  11

NUMSEC =  3    LSECT( 1) = 10  LSECT( 2) = 10  LSECT( 3) = 10

DATA ON CARD NUMBER  12

AS( 1) =  2.6460E+04 FT**2  VOS( 1) =  4.0600E+04 V  TCS( 1) =  2.7300E-01 A  HLS( 1) =  1.5720E+04 FT
ACS( 1) =  8.2500E-02 IN  BS( 1) =  5.5000E+00 IN  NNS( 1) =  1.2000E+01

DATA ON CARD NUMBER  13

SYS( 1) =  3.6250E+00 IN  VGS( 1) =  3.2724E+05 FT**3/MIN  VGASS( 1) =  4.1000E+00 FT/SEC  TEMPS( 1) =  3.1500E+02 F
PS( 1) =  1.0000E+00 ATM  VISS( 1) =  2.2900E-05 KG/M-SEC  LINCS( 1) =  9.0000E-01 FT

DATA ON CARD NUMBER  14

AS( 2) =  2.6460E+04 FT**2  VOS( 2) =  4.2100E+04 V  TCS( 2) =  4.3300E-01 A  HLS( 2) =  1.5720E+04 FT
ACS( 2) =  8.2500E-02 IN  BS( 2) =  5.5000E+00 IN  NNS( 2) =  1.2000E+01

DATA ON CARD NUMBER  15
```

```
SVS( 2) =  3.6250E+00 IN  VGS( 2) =  3.2724E+05 FT**3/MIN  VGASS( 2) =  4.1000E+00 FT/SEC  TEMPS( 2) =  3.1500E+02 F

PS( 2) =  1.0000E+00 ATM  VISS( 2) =  2.2900E-05 KG/M-SEC  LINCS( 2) =  9.0000E-01 FT

DATA ON CARD NUMBER  16

AS( 3) =  2.6460E+04 FT**2  VOS( 3) =  4.2450E+04 V  TCS( 3) =  5.5800E-01 A  WLS( 3) =  1.5720E+04 FT

ACS( 3) =  8.2500E-02 IN  RS( 3) =  5.5000E+00 IN  NWS( 3) =  1.2000E+01

DATA ON CARD NUMBER  17

SVS( 3) =  3.6250E+00 IN  VGS( 3) =  3.2724E+05 FT**3/MIN  VGASS( 3) =  4.1000E+00 FT/SEC  TEMPS( 3) =  3.1500E+02 F

PS( 3) =  1.0000E+00 ATM  VISS( 3) =  2.2900E-05 KG/M-SEC  LINCS( 3) =  9.0000E-01 FT
```

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INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


FULL-SCALE,COLD-SIDE ESP; PLANT A; SCA=243FT2/1000ACFM;J=15.9UA/FT2


CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2        APPLIED VOLTAGE =  4.060E+04 VOLTS       TOTAL CURRENT =  2.730E-01 AMPS
WIRE TO PLATE =  1.397E-01 M           CORONA WIRE RADIUS =  2.096E-03 M        CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  5.694E-05 AMP/M           CURRENT DENSITY =  1.109E-04 AMP/M2      DEPOSIT E FIELD =  5.547E+04 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M        GAS FLOW RATE =  1.548E+02 M3/SEC        GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                PRESSURE =   1.000 ATM                   VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  5.335E+02 M/SEC    PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC        LENGTH INCR. =0.27450000 M               INPUT EFF./INCR. = 16.81

ROVRI     ERAVG        EPLT         AFID         CMCD      MMD         WEIGHT      DUST LAYER   J(PART)      J(ION)    INCR. NO.

3.1566    2.906E+05   2.0924E+05   2.1825E+12    11.1    2.29E-05    1.523E-03    5.750E-02    4.82E-07    1.10E-04      1
2.5167    2.906E+05   1.9692E+05   2.7374E+12    11.1    2.27E-05    1.195E-03    4.511E-02    6.23E-07    1.10E-04      2
2.0587    2.906E+05   1.8844E+05   3.3464E+12    11.1    2.22E-05    6.878E-04    2.596E-02    5.22E-07    1.10E-04      3
1.7622    2.906E+05   1.8269E+05   3.9093E+12    11.1    2.13E-05    3.653E-04    1.379E-02    4.11E-07    1.11E-04      4
1.5647    2.906E+05   1.7873E+05   4.4030E+12    11.1    1.91E-05    1.968E-04    7.426E-03    3.38E-07    1.11E-04      5
1.4261    2.906E+05   1.7588E+05   4.8308E+12    11.1    1.20E-05    1.134E-04    4.282E-03    2.93E-07    1.11E-04      6
1.3250    2.906E+05   1.7378E+05   5.1994E+12    11.1    7.46E-06    7.195E-05    2.715E-03    2.64E-07    1.11E-04      7
1.2494    2.906E+05   1.7218E+05   5.5139E+12    11.1    5.13E-06    5.023E-05    1.896E-03    2.42E-07    1.11E-04      8
1.1921    2.906E+05   1.7096E+05   5.7788E+12    11.1    3.90E-06    3.792E-05    1.431E-03    2.25E-07    1.11E-04      9
1.1484    2.906E+05   1.7002E+05   5.9990E+12    11.1    3.19E-06    3.025E-05    1.142E-03    2.10E-07    1.11E-04     10

CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2        APPLIED VOLTAGE =  4.210E+04 VOLTS       TOTAL CURRENT =  4.330E-01 AMPS
WIRE TO PLATE =  1.397E-01 M           CORONA WIRE RADIUS =  2.096E-03 M        CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  9.031E-05 AMP/M           CURRENT DENSITY =  1.760E-04 AMP/M2      DEPOSIT E FIELD =  8.798E+04 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M        GAS FLOW RATE =  1.548E+02 M3/SEC        GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                PRESSURE =   1.000 ATM                   VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC  MEAN THERMAL SPEED =  5.335E+02 M/SEC    PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC        LENGTH INCR. =0.27450000 M               INPUT EFF./INCR. = 16.81

ROVRI     ERAVG        EPLT         AFID         CMCD      MMD         WEIGHT      DUST LAYER   J(PART)      J(ION)    INCR. NO.

1.0750    3.014E+05   1.8591E+05   9.8018E+12    17.6    2.68E-06    2.766E-05    1.044E-03    2.22E-07    1.76E-04     11
1.0577    3.014E+05   1.8536E+05   9.9629E+12    17.6    2.41E-06    2.324E-05    8.770E-04    2.10E-07    1.76E-04     12
1.0443    3.014E+05   1.8495E+05   1.0090E+13    17.6    2.28E-06    1.981E-05    7.476E-04    1.98E-07    1.76E-04     13
1.0341    3.014E+05   1.8463E+05   1.0190E+13    17.6    2.17E-06    1.707E-05    6.441E-04    1.86E-07    1.76E-04     14
1.0263    3.014E+05   1.8463E+05   1.0268E+13    17.6    2.08E-06    1.485E-05    5.604E-04    1.74E-07    1.76E-04     15
1.0202    3.014E+05   1.8463E+05   1.0328E+13    17.6    2.00E-06    1.300E-05    4.905E-04    1.64E-07    1.76E-04     16
1.0156    3.014E+05   1.8463E+05   1.0375E+13    17.6    1.93E-06    1.144E-05    4.317E-04    1.53E-07    1.76E-04     17
1.0120    3.014E+05   1.8463E+05   1.0412E+13    17.6    1.87E-06    1.011E-05    3.814E-04    1.44E-07    1.76E-04     18
1.0093    3.014E+05   1.8463E+05   1.0440E+13    17.6    1.80E-06    8.962E-06    3.382E-04    1.35E-07    1.76E-04     19
1.0072    3.014E+05   1.8463E+05   1.0462E+13    17.6    1.74E-06    7.970E-06    3.008E-04    1.26E-07    1.76E-04     20

CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  2.7450 M
```

```
COLLECTION AREA =  2.461E+03 M2         APPLIED VOLTAGE =  4.245E+04 VOLTS       TOTAL CURRENT =  5.580E-01 AMPS
WIRE TO PLATE =  1.397E-01 M            CORONA WIRE RADIUS =  2.096E-03 M        CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  1.164E-04 AMP/M            CURRENT DENSITY =  2.268E-04 AMP/M2      DEPOSIT E FIELD =  1.134E+05 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M         GAS FLOW RATE =  1.548E+02 M3/SEC        GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                 PRESSURE =   1.000 ATM                   VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  5.335E+02 M/SEC    PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC         LENGTH INCR. =0.27450000 M               INPUT EFF./INCR. = 16.81

ROVRI      ERAVG        EPLT         AFID         CMCD      MMD         WEIGHT      DUST LAYER   J(PART)      J(ION)     INCR. NO.

1.0043   3.039E+05   1.9360E+05   1.3409E+13     22.7    1.69E-06   7.453E-06   2.813E-04   1.24E-07    2.27E-04       21
1.0033   3.039E+05   1.9360E+05   1.3423E+13     22.7    1.63E-06   6.633E-06   2.503E-04   1.16E-07    2.27E-04       22
1.0026   3.039E+05   1.9360E+05   1.3433E+13     22.7    1.57E-06   5.916E-06   2.233E-04   1.09E-07    2.27E-04       23
1.0020   3.039E+05   1.9360E+05   1.3441E+13     22.7    1.52E-06   5.287E-06   1.995E-04   1.02E-07    2.27E-04       24
1.0015   3.039E+05   1.9360E+05   1.3447E+13     22.7    1.47E-06   4.727E-06   1.784E-04   9.49E-08    2.27E-04       25
1.0012   3.039E+05   1.9360E+05   1.3452E+13     22.7    1.43E-06   4.235E-06   1.598E-04   8.86E-08    2.27E-04       26
1.0009   3.039E+05   1.9360E+05   1.3455E+13     22.7    1.38E-06   3.798E-06   1.433E-04   8.27E-08    2.27E-04       27
1.0007   3.039E+05   1.9360E+05   1.3458E+13     22.7    1.34E-06   3.412E-06   1.288E-04   7.72E-08    2.27E-04       28
1.0005   3.039E+05   1.9360E+05   1.3460E+13     22.7    1.30E-06   3.068E-06   1.158E-04   7.19E-08    2.27E-04       29
1.0004   3.039E+05   1.9360E+05   1.3462E+13     22.7    1.26E-06   2.763E-06   1.043E-04   6.71E-08    2.27E-04       30
EST. EFFICIENCY = 99.60     UNCORRECTED COMPUTED EFFICIENCY = 99.37


INCREMENTAL ANALYSIS OF PRECIPITATOR PERFORMANCE


FULL-SCALE,COLD-SIDE ESP; PLANT A; SCA=243FT2/1000ACFM;J=15.9UA/FT2


CALCULATION IS IN SECTION NO. = 1 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2         APPLIED VOLTAGE =  4.060E+04 VOLTS       TOTAL CURRENT =  2.730E-01 AMPS
WIRE TO PLATE =  1.397E-01 M            CORONA WIRE RADIUS =  2.096E-03 M        CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  5.694E-05 AMP/M            CURRENT DENSITY =  1.109E-04 AMP/M2      DEPOSIT E FIELD =  5.547E+04 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M         GAS FLOW RATE =  1.548E+02 M3/SEC        GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K                 PRESSURE =   1.000 ATM                   VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC   MEAN THERMAL SPEED =  5.335E+02 M/SEC    PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC         LENGTH INCR. =0.27450000 M               INPUT EFF./INCR. = 15.55

ROVRI      ERAVG        EPLT         AFID         CMCD      MMD         WEIGHT      DUST LAYER   J(PART)      J(ION)     INCR. NO.

2.9945   2.906E+05   2.0637E+05   2.3006E+12     11.1    2.29E-05   1.542E-03   5.821E-02   5.03E-07    1.10E-04        1
2.4206   2.906E+05   1.9518E+05   2.8460E+12     11.1    2.26E-05   1.193E-03   4.502E-02   6.34E-07    1.10E-04        2
2.0061   2.906E+05   1.8744E+05   3.4340E+12     11.1    2.22E-05   6.816E-04   2.572E-02   5.25E-07    1.10E-04        3
1.7356   2.906E+05   1.8216E+05   3.9694E+12     11.1    2.13E-05   3.610E-04   1.362E-02   4.13E-07    1.11E-04        4
1.5533   2.906E+05   1.7849E+05   4.4353E+12     11.1    1.89E-05   1.944E-04   7.335E-03   3.39E-07    1.11E-04        5
1.4239   2.906E+05   1.7584E+05   4.8384E+12     11.1    1.18E-05   1.122E-04   4.234E-03   2.93E-07    1.11E-04        6
1.3282   2.906E+05   1.7384E+05   5.1869E+12     11.1    7.38E-06   7.128E-05   2.690E-03   2.64E-07    1.11E-04        7
1.2557   2.906E+05   1.7232E+05   5.4863E+12     11.1    5.08E-06   4.985E-05   1.881E-03   2.42E-07    1.11E-04        8
1.2000   2.906E+05   1.7113E+05   5.7412E+12     11.1    3.88E-06   3.768E-05   1.422E-03   2.25E-07    1.11E-04        9
1.1568   2.906E+05   1.7021E+05   5.9556E+12     11.1    3.18E-06   3.009E-05   1.136E-03   2.10E-07    1.11E-04       10
CALCULATION IS IN SECTION NO. = 2 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2         APPLIED VOLTAGE =  4.210E+04 VOLTS       TOTAL CURRENT =  4.330E-01 AMPS
WIRE TO PLATE =  1.397E-01 M            CORONA WIRE RADIUS =  2.096E-03 M        CORONA WIRE LENGTH =  4.795E+03 M
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CURRENT/M =  9.031E-05 AMP/M          CURRENT DENSITY =  1.760E-04 AMP/M2     DEPOSIT E FIELD =  8.798E+04 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M       GAS FLOW RATE =  1.548E+02 M3/SEC       GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K               PRESSURE =   1.000 ATM                  VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC MEAN THERMAL SPEED =  5.335E+02 M/SEC   PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC       LENGTH INCR. =0.27450000 M              INPUT EFF./INCR. = 15.55

ROVRI     ERAVG        EPLT         AFID       CMCD      MMD         WEIGHT     DUST LAYER   J(PART)       J(ION)   INCR. NO.

1.0805   3.014E+05  1.8607E+05  9.7525E+12    17.6   2.67E-06    2.752E-05   1.039E-03   2.21E-07     1.76E-04       11
1.0628   3.014E+05  1.8553E+05  9.9149E+12    17.6   2.40E-06    2.313E-05   8.729E-04   2.10E-07     1.76E-04       12
1.0490   3.014E+05  1.8510E+05  1.0045E+13    17.6   2.27E-06    1.972E-05   7.442E-04   1.97E-07     1.76E-04       13
1.0383   3.014E+05  1.8476E+05  1.0149E+13    17.6   2.17E-06    1.699E-05   6.413E-04   1.85E-07     1.76E-04       14
1.0299   3.014E+05  1.8476E+05  1.0231E+13    17.6   2.08E-06    1.479E-05   5.580E-04   1.74E-07     1.76E-04       15
1.0234   3.014E+05  1.8476E+05  1.0296E+13    17.6   2.00E-06    1.294E-05   4.885E-04   1.63E-07     1.76E-04       16
1.0183   3.014E+05  1.8476E+05  1.0348E+13    17.6   1.93E-06    1.139E-05   4.300E-04   1.53E-07     1.76E-04       17
1.0143   3.014E+05  1.8476E+05  1.0388E+13    17.6   1.86E-06    1.007E-05   3.799E-04   1.43E-07     1.76E-04       18
1.0112   3.014E+05  1.8476E+05  1.0420E+13    17.6   1.80E-06    8.928E-06   3.369E-04   1.34E-07     1.76E-04       19
1.0088   3.014E+05  1.8476E+05  1.0445E+13    17.6   1.74E-06    7.939E-06   2.996E-04   1.26E-07     1.76E-04       20

CALCULATION IS IN SECTION NO. = 3 AND THE SECTION LENGTH IS =  2.7450 M

COLLECTION AREA =  2.461E+03 M2       APPLIED VOLTAGE =  4.245E+04 VOLTS      TOTAL CURRENT =  5.580E-01 AMPS
WIRE TO PLATE =  1.397E-01 M          CORONA WIRE RADIUS =  2.096E-03 M       CORONA WIRE LENGTH =  4.795E+03 M
CURRENT/M =  1.164E-04 AMP/M          CURRENT DENSITY =  2.268E-04 AMP/M2     DEPOSIT E FIELD =  1.134E+05 VOLT/M
1/2 WIRE TO WIRE =  9.208E-02 M       GAS FLOW RATE =  1.548E+02 M3/SEC       GAS VELOCITY =  1.250E+00 M/SEC
TEMPERATURE = 430.000 K               PRESSURE =   1.000 ATM                  VISCOSITY =  2.290E-05 KG/M-SEC
ION MOBILITY =  3.463E-04 M2/VOLT-SEC MEAN THERMAL SPEED =  5.335E+02 M/SEC   PART. PATH PARAM. =  8.246E-08 M
DUST WEIGHT =  6.969E-01 KG/SEC       LENGTH INCR. =0.27450000 M              INPUT EFF./INCR. = 15.55

ROVRI     ERAVG        EPLT         AFID       CMCD      MMD         WEIGHT     DUST LAYER   J(PART)       J(ION)   INCR. NO.

1.0054   3.039E+05  1.9363E+05  1.3395E+13    22.7   1.68E-06    7.422E-06   2.801E-04   1.24E-07     2.27E-04       21
1.0042   3.039E+05  1.9363E+05  1.3411E+13    22.7   1.62E-06    6.606E-06   2.493E-04   1.16E-07     2.27E-04       22
1.0033   3.039E+05  1.9363E+05  1.3423E+13    22.7   1.57E-06    5.892E-06   2.224E-04   1.08E-07     2.27E-04       23
1.0026   3.039E+05  1.9363E+05  1.3433E+13    22.7   1.52E-06    5.266E-06   1.987E-04   1.01E-07     2.27E-04       24
1.0020   3.039E+05  1.9363E+05  1.3440E+13    22.7   1.47E-06    4.709E-06   1.777E-04   9.46E-08     2.27E-04       25
1.0016   3.039E+05  1.9363E+05  1.3446E+13    22.7   1.42E-06    4.219E-06   1.592E-04   8.84E-08     2.27E-04       26
1.0012   3.039E+05  1.9363E+05  1.3451E+13    22.7   1.38E-06    3.783E-06   1.428E-04   8.25E-08     2.27E-04       27
1.0010   3.039E+05  1.9363E+05  1.3454E+13    22.7   1.34E-06    3.399E-06   1.283E-04   7.69E-08     2.27E-04       28
1.0008   3.039E+05  1.9363E+05  1.3457E+13    22.7   1.30E-06    3.057E-06   1.154E-04   7.17E-08     2.27E-04       29
1.0006   3.039E+05  1.9363E+05  1.3459E+13    22.7   1.26E-06    2.753E-06   1.039E-04   6.69E-08     2.27E-04       30
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CHARGING RATES FOR PARTICLE SIZES FROM SUBROUTINE CHARGN OR CHGSUM

SRI THEORY USED FOR PARTICLE CHARGING

INCREMENT NO.     Q/QSATF FOR INDICATED PARTICLE SIZES

    0.2000E-06   0.4000E-06   0.7000E-06   0.1100E-05   0.1600E-05   0.2500E-05   0.3500E-05   0.4500E-05
  1  0.5293        0.5206       0.4911       0.4693       0.4555       0.4436       0.4373       0.4339
  2  0.7611        0.7536       0.7120       0.6794       0.6576       0.6388       0.6293       0.6244
  3  0.9222        0.9229       0.8609       0.8104       0.7773       0.7500       0.7370       0.7308
  4  1.0587        1.0651       0.9861       0.9085       0.8596       0.8215       0.8046       0.7969
  5  1.1669        1.1677       1.0774       0.9919       0.9244       0.8725       0.8508       0.8413
  6  1.2554        1.2469       1.1432       1.0502       0.9793       0.9122       0.8847       0.8733
  7  1.3299        1.3110       1.1942       1.0931       1.0184       0.9455       0.9113       0.8975
  8  1.3939        1.3647       1.2357       1.1268       1.0478       0.9721       0.9330       0.9167
  9  1.4498        1.4106       1.2706       1.1544       1.0712       0.9920       0.9512       0.9324
 10  1.4992        1.4505       1.3005       1.1777       1.0906       1.0079       0.9644       0.9453
 11  1.5706        1.5100       1.3468       1.2156       1.1234       1.0368       0.9921       0.9710
 12  1.6301        1.5584       1.3836       1.2449       1.1480       1.0573       1.0088       0.9886
 13  1.6809        1.5991       1.4141       1.2687       1.1677       1.0732       1.0216       0.9982
 14  1.7252        1.6342       1.4401       1.2888       1.1840       1.0861       1.0319       1.0055
 15  1.7644        1.6650       1.4627       1.3060       1.1978       1.0969       1.0405       1.0117
 16  1.7996        1.6924       1.4827       1.3212       1.2099       1.1062       1.0479       1.0172
 17  1.8314        1.7170       1.5005       1.3346       1.2206       1.1143       1.0543       1.0220
 18  1.8604        1.7394       1.5166       1.3467       1.2301       1.1216       1.0600       1.0220
 19  1.8871        1.7598       1.5313       1.3577       1.2388       1.1281       1.0652       1.0220
 20  1.9117        1.7786       1.5448       1.3678       1.2466       1.1340       1.0652       1.0220
 21  1.9412        1.8014       1.5613       1.3802       1.2565       1.1416       1.0719       1.0285
 22  1.9683        1.8221       1.5762       1.3914       1.2654       1.1484       1.0719       1.0285
 23  1.9932        1.8411       1.5899       1.4017       1.2735       1.1545       1.0719       1.0285
 24  2.0163        1.8587       1.6025       1.4111       1.2809       1.1601       1.0719       1.0285
 25  2.0378        1.8750       1.6141       1.4197       1.2877       1.1601       1.0719       1.0285
 26  2.0579        1.8903       1.6250       1.4278       1.2940       1.1601       1.0719       1.0285
 27  2.0768        1.9045       1.6351       1.4353       1.2940       1.1601       1.0719       1.0285
 28  2.0947        1.9180       1.6447       1.4424       1.2940       1.1601       1.0719       1.0285
 29  2.1116        1.9307       1.6537       1.4424       1.2940       1.1601       1.0719       1.0285
 30  2.1276        1.9427       1.6622       1.4424       1.2940       1.1601       1.0719       1.0285

    0.6000E-05   0.8500E-05   0.1250E-04   0.2000E-04   0.2750E-04
  1  0.4311        0.4289       0.4277       0.4272       0.4270
  2  0.6208        0.6184       0.6174       0.6170       0.6170
  3  0.7265        0.7241       0.7232       0.7230       0.7229
  4  0.7919        0.7893       0.7884       0.7883       0.7883
  5  0.8355        0.8326       0.8318       0.8317       0.8317
  6  0.8664        0.8632       0.8624       0.8623       0.8622
  7  0.8895        0.8859       0.8850       0.8849       0.8849
  8  0.9074        0.9033       0.9024       0.9023       0.9023
  9  0.9217        0.9171       0.9161       0.9160       0.9160
 10  0.9334        0.9283       0.9272       0.9271       0.9271
 11  0.9583        0.9532       0.9521       0.9520       0.9520
 12  0.9754        0.9699       0.9687       0.9686       0.9686
 13  0.9870        0.9814       0.9803       0.9802       0.9802
 14  0.9928        0.9889       0.9879       0.9878       0.9878
 15  0.9958        0.9919       0.9918       0.9917       0.9917
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16  0.9958        0.9919        0.9918        0.9917        0.9917
17  0.9958        0.9919        0.9918        0.9917        0.9917
18  0.9958        0.9919        0.9918        0.9917        0.9917
19  0.9958        0.9919        0.9918        0.9917        0.9917
20  0.9958        0.9919        0.9918        0.9917        0.9917
21  1.0021        0.9996        0.9992        0.9991        0.9991
22  1.0021        0.9996        0.9992        0.9991        0.9991
23  1.0021        0.9996        0.9992        0.9991        0.9991
24  1.0021        0.9996        0.9992        0.9991        0.9991
25  1.0021        0.9996        0.9992        0.9991        0.9991
26  1.0021        0.9996        0.9992        0.9991        0.9991
27  1.0021        0.9996        0.9992        0.9991        0.9991
28  1.0021        0.9996        0.9992        0.9991        0.9991
29  1.0021        0.9996        0.9992        0.9991        0.9991
30  1.0021        0.9996        0.9992        0.9991        0.9991
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CHARGE ACCUMULATED ON PARTICLE SIZES IN EACH INCREMENT

INCREMENT        CHARGE FOR INDICATED PARTICLE SIZES

        0.2000E-06    0.4000E-06    0.7000E-06    0.1100E-05    0.1600E-05    0.2500E-05    0.3500E-05    0.4500E-05
  1    0.94287E-18   0.28449E-17   0.75571E-17   0.17331E-16   0.35188E-16   0.83125E-16   0.16024E-15   0.26252E-15
  2    0.13559E-17   0.41186E-17   0.10957E-16   0.25090E-16   0.50804E-16   0.11970E-15   0.23057E-15   0.37780E-15
  3    0.16428E-17   0.50437E-17   0.13248E-16   0.29927E-16   0.60052E-16   0.14053E-15   0.27004E-15   0.44217E-15
  4    0.18860E-17   0.58206E-17   0.15174E-16   0.33551E-16   0.66406E-16   0.15394E-15   0.29479E-15   0.48215E-15
  5    0.20787E-17   0.63813E-17   0.16580E-16   0.36630E-16   0.71415E-16   0.16349E-15   0.31172E-15   0.50905E-15
  6    0.22364E-17   0.68142E-17   0.17592E-16   0.38783E-16   0.75655E-16   0.17093E-15   0.32416E-15   0.52837E-15
  7    0.23692E-17   0.71647E-17   0.18377E-16   0.40365E-16   0.78676E-16   0.17717E-15   0.33388E-15   0.54303E-15
  8    0.24832E-17   0.74579E-17   0.19016E-16   0.41610E-16   0.80944E-16   0.18215E-15   0.34185E-15   0.55465E-15
  9    0.25828E-17   0.77087E-17   0.19552E-16   0.42631E-16   0.82752E-16   0.18589E-15   0.34850E-15   0.56412E-15
 10    0.26707E-17   0.79269E-17   0.20012E-16   0.43493E-16   0.84248E-16   0.18887E-15   0.35337E-15   0.57194E-15
 11    0.27980E-17   0.82517E-17   0.20725E-16   0.44890E-16   0.86785E-16   0.19429E-15   0.36352E-15   0.58747E-15
 12    0.29039E-17   0.85163E-17   0.21292E-16   0.45972E-16   0.88688E-16   0.19813E-15   0.36963E-15   0.59816E-15
 13    0.29944E-17   0.87389E-17   0.21761E-16   0.46852E-16   0.90205E-16   0.20110E-15   0.37430E-15   0.60393E-15
 14    0.30734E-17   0.89308E-17   0.22161E-16   0.47592E-16   0.91463E-16   0.20351E-15   0.37807E-15   0.60836E-15
 15    0.31433E-17   0.90990E-17   0.22509E-16   0.48230E-16   0.92536E-16   0.20554E-15   0.38123E-15   0.61214E-15
 16    0.32059E-17   0.92487E-17   0.22816E-16   0.48789E-16   0.93469E-16   0.20728E-15   0.38393E-15   0.61545E-15
 17    0.32626E-17   0.93833E-17   0.23091E-16   0.49286E-16   0.94293E-16   0.20881E-15   0.38630E-15   0.61838E-15
 18    0.33143E-17   0.95054E-17   0.23339E-16   0.49733E-16   0.95031E-16   0.21016E-15   0.38839E-15   0.61838E-15
 19    0.33618E-17   0.96172E-17   0.23565E-16   0.50139E-16   0.95698E-16   0.21138E-15   0.39028E-15   0.61838E-15
 20    0.34057E-17   0.97201E-17   0.23773E-16   0.50510E-16   0.96306E-16   0.21249E-15   0.39028E-15   0.61838E-15
 21    0.34583E-17   0.98443E-17   0.24026E-16   0.50970E-16   0.97071E-16   0.21392E-15   0.39275E-15   0.62230E-15
 22    0.35064E-17   0.99575E-17   0.24256E-16   0.51385E-16   0.97758E-16   0.21519E-15   0.39275E-15   0.62230E-15
 23    0.35507E-17   0.10061E-16   0.24466E-16   0.51762E-16   0.98381E-16   0.21634E-15   0.39275E-15   0.62230E-15
 24    0.35919E-17   0.10158E-16   0.24660E-16   0.52109E-16   0.98951E-16   0.21738E-15   0.39275E-15   0.62230E-15
 25    0.36302E-17   0.10247E-16   0.24839E-16   0.52430E-16   0.99476E-16   0.21738E-15   0.39275E-15   0.62230E-15
 26    0.36661E-17   0.10330E-16   0.25006E-16   0.52727E-16   0.99962E-16   0.21738E-15   0.39275E-15   0.62230E-15
 27    0.36998E-17   0.10408E-16   0.25162E-16   0.53005E-16   0.99962E-16   0.21738E-15   0.39275E-15   0.62230E-15
 28    0.37316E-17   0.10482E-16   0.25309E-16   0.53266E-16   0.99962E-16   0.21738E-15   0.39275E-15   0.62230E-15
 29    0.37617E-17   0.10551E-16   0.25448E-16   0.53266E-16   0.99962E-16   0.21738E-15   0.39275E-15   0.62230E-15
 30    0.37902E-17   0.10617E-16   0.25578E-16   0.53266E-16   0.99962E-16   0.21738E-15   0.39275E-15   0.62230E-15

        0.6000E-05    0.8500E-05    0.1250E-04    0.2000E-04    0.2750E-04
  1    0.46333E-15   0.92477E-15   0.19937E-14   0.50962E-14   0.96313E-14
  2    0.66724E-15   0.13333E-14   0.28776E-14   0.73611E-14   0.13915E-13
  3    0.78089E-15   0.15611E-14   0.33708E-14   0.86247E-14   0.16304E-13
  4    0.85113E-15   0.17016E-14   0.36750E-14   0.94041E-14   0.17778E-13
  5    0.89798E-15   0.17950E-14   0.38770E-14   0.99217E-14   0.18756E-13
  6    0.93122E-15   0.18610E-14   0.40195E-14   0.10287E-13   0.19446E-13
  7    0.95603E-15   0.19099E-14   0.41250E-14   0.10557E-13   0.19957E-13
  8    0.97529E-15   0.19475E-14   0.42060E-14   0.10764E-13   0.20349E-13
  9    0.99068E-15   0.19773E-14   0.42701E-14   0.10928E-13   0.20659E-13
 10    0.10032E-14   0.20014E-14   0.43218E-14   0.11060E-13   0.20909E-13
 11    0.10300E-14   0.20550E-14   0.44377E-14   0.11357E-13   0.21470E-13
 12    0.10483E-14   0.20910E-14   0.45154E-14   0.11556E-13   0.21846E-13
 13    0.10608E-14   0.21160E-14   0.45692E-14   0.11694E-13   0.22107E-13
 14    0.10671E-14   0.21321E-14   0.46047E-14   0.11785E-13   0.22279E-13
 15    0.10703E-14   0.21386E-14   0.46226E-14   0.11831E-13   0.22367E-13
 16    0.10703E-14   0.21386E-14   0.46226E-14   0.11831E-13   0.22367E-13
 17    0.10703E-14   0.21386E-14   0.46226E-14   0.11831E-13   0.22367E-13
 18    0.10703E-14   0.21386E-14   0.46226E-14   0.11831E-13   0.22367E-13
 19    0.10703E-14   0.21386E-14   0.46226E-14   0.11831E-13   0.22367E-13
```

```
20   0.10703E-14   0.21386E-14   0.46224E-14   0.11831E-13   0.22367F-13
21   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534E-13
22   0.10771E-14   0.21551E-14   0.46577E-14   0.11920E-13   0.22534E-13
23   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534E-13
24   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534F-13
25   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534F-13
26   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534E-13
27   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534E-13
28   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534E-13
29   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534E-13
30   0.10771E-14   0.21551E-14   0.46572E-14   0.11920E-13   0.22534E-13
```

```
PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO. 1 OF CORRECTION PARAMETERS

   SIZE      CCF   INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W    COR. P
 2.000E-07  2.123  0.033   0.7460        0.4596      95.6337     6.565    4.3663    95.4127     6.462    4.5873
 4.000E-07  1.530  0.253   7.7149        4.6397      94.1103     5.938    5.8897    93.9591     5.885    6.0409
 7.000E-07  1.297  0.903  23.7497       14.5819      94.9201     6.248    5.0799    94.6806     6.151    5.3194
 1.100E-06  1.188  0.815  15.2607       10.1210      96.3834     6.960    3.6166    95.9093     6.702    4.0907
 1.600E-06  1.130  1.520  19.0143       13.5163      97.5839     7.806    2.4161    97.0708     7.402    2.9292
 2.500E-06  1.083  3.524  22.9679       18.8810      98.7412     9.173    1.2588    98.2351     8.464    1.7649
 3.500E-06  1.059  1.652   5.9857        6.9689      99.3002    10.404    0.6998    98.6104     8.966    1.3896
 4.500E-06  1.046  1.652   3.5711        6.6668      99.5825    11.487    0.4175    98.6706     9.059    1.3294
 6.000E-06  1.035  1.982   0.8603        5.9268      99.9162    14.853    0.0838    99.0150     9.687    0.9850
 8.500E-06  1.024  3.304   0.0861        6.4448      99.9950    20.751    0.0050    99.3575    10.583    0.6425
 1.250E-05  1.017  4.846   0.0025        5.1520      99.9999    33.981    0.0001    99.6498    11.855    0.3502
 2.000E-05  1.010 12.115   0.0062        4.1915      99.9999    54.024    0.0001    99.8860    14.209    0.1140
 2.750E-05  1.008 67.401   0.0346        2.4497      99.9999    74.070    0.0001    99.9880    18.934    0.0120

   EFFICIENCY - STATED = 99.37     COMPUTED = 99.3736     CONVERGENCE OBTAINED


   ADJUSTED NO-RAP EFF. =  99.8069
   MMD OF INLET SIZE DISTRIBUTION =  4.465E+01
   SIGMAP OF INLET SIZE DISTRIBUTION =  5.122E+00
   LOG-NORMAL GOODNESS OF FIT =  0.984
   MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.336E+00
   SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  1.919E+00
   LOG-NORMAL GOODNESS OF FIT =  0.997
   PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 13.103


   SIGMAG=    0.000  WITH  0.000 SNEAKAGE OVER    3.000  STAGES
   NTEMP = 1
   RMMD =  6.00
   RSIGMA = 2.50
   CORR. EFF. =  99.6706
   CORRECTED MMD OF EFFLUENT =  2.687E+00
   CORRECTED SIGMAP OF EFFLUENT =  2.816E+00
   LOG-NORMAL GOODNESS OF FIT =  0.988
   CORRECTED PRECIPITATION RATE PARAMETER =   11.98
```

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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP          RAPPING PUFF      NO-RAP+RAP PUFF     RAPPING PUFF      PARTICLE
MIG. VEL.(CM/SEC)   EFFICIENCY(%)     DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 2.702E+00            7.243E+01           2.146E-01           1.086E-02           2.254E-01         5.350E-02        2.000E-07
 2.814E+00            7.387E+01           4.772E+00           1.225E-01           4.895E+00         2.806E-01        4.000E-07
 3.377E+00            8.003E+01           1.277E+01           6.019E-01           1.337E+01         1.586E+00        7.000E-07
 4.223E+00            8.666E+01           1.311E+01           1.719E+00           1.483E+01         2.834E+00        1.100E-06
 5.296E+00            9.200E+01           1.583E+01           3.362E+00           1.919E+01         5.720E+00        1.600E-06
 7.223E+00            9.681E+01           1.482E+01           5.960E+00           2.078E+01         1.308E+01        2.500E-06
 9.331E+00            9.883E+01           8.238E+00           8.120E+00           1.636E+01         8.358E+00        3.500E-06
 1.149E+01            9.958E+01           4.206E+00           9.186E+00           1.339E+01         1.105E+01        4.500E-06
 1.485E+01            9.992E+01           8.992E-01           9.667E+00           1.057E+01         1.310E+01        6.000E-06
 2.075E+01            9.999E+01           7.141E-02           9.044E+00           9.115E+00         1.545E+01        8.500E-06
 3.398E+01            1.000E+02           2.022E-03           7.140E+00           7.142E+00         1.245E+01        1.250E-05
 5.402E+01            1.000E+02           3.769E-03           4.331E+00           4.335E+00         1.013E+01        2.000E-05
 7.407E+01            1.000E+02           6.250E-02           7.544E+00           7.606E+00         5.918E+00        2.750E-05
```

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                                       SUMMARY TABLE OF ESP OPERATING
                                        PARAMETERS AND PERFORMANCE


                                             DATA SET NUMBER   1

            ESP PERFORMANCE:     EFFICIENCY =  99.6706 %     SCA =  4.769E+01 M**2/(M**3/SEC)

            ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.172E+04 V

                                       AVG. CURRENT DENSITY =   17.12 NA/CM**2

                                       RESISTIVITY =  5.000E+10 OHM-CM

            SIZE DISTRIBUTIONS:     INLET MMD =  4.465E+01 UM     INLET SIGMAP =  5.122E+00

                                    OUTLET MMD =  2.687E+00 UM     OUTLET SIGMAP =  2.816E+00

            NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.00 /SECTION     GAS VELOCITY SIGMAG = 0.00

                                     RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00

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PARTICLE SIZE RANGE STATISTICS

CORRECTIONS FOR NONIDEALITIES USING SET NO. 2 OF CORRECTION PARAMETERS

   SIZE      CCF   INLET % OUTLET % COR. OUTLET % NO-RAP EFF. NO-RAP W  NO-RAP P  COR. EFF.   COR. W     COR. P
 2.000E-07  2.123  0.033   0.4509       0.3301       92.3311     5.384    7.6689   91.9336    5.278      8.0664
 4.000E-07  1.530  0.253   4.4488       3.1822       90.1301     4.855    9.8699   89.8582    4.798     10.1418
 7.000E-07  1.297  0.903  14.5658      10.6218       90.9462     5.036    9.0538   90.5155    4.939      9.4845
 1.100E-06  1.188  0.815  10.5527       8.2078       92.7324     5.497    7.2676   91.8797    5.264      8.1203
 1.600E-06  1.130  1.520  15.3888      12.4518       94.3174     6.013    5.6826   93.3947    5.697      6.6053
 2.500E-06  1.083  3.524  25.0413      21.4094       96.0115     6.755    3.9885   95.1014    6.324      4.8986
 3.500E-06  1.059  1.652   9.1685       8.9240       96.8849     7.273    3.1151   95.6443    6.570      4.3557
 4.500E-06  1.046  1.652   7.9239       8.8757       97.3078     7.579    2.6922   95.6679    6.502      4.3321
 6.000E-06  1.035  1.982   5.1532       7.5712       98.5406     8.863    1.4594   96.9199    7.297      3.0801
 8.500E-06  1.024  3.304   4.6876       7.9611       99.2037    10.133    0.7963   98.0571    8.263      1.9429
 1.250E-05  1.017  4.846   2.3997       5.4557       99.7220    12.340    0.2780   99.0922    9.859      0.9078
 2.000E-05  1.010 12.115   0.1864       3.2093       99.9914    19.619    0.0086   99.7864   12.892      0.2136
 2.750E-05  1.008 67.401   0.0323       1.7999       99.9997    74.070    0.0003   99.9785   17.703      0.0215

    EFFICIENCY - STATED = 99.37     COMPUTED = 99.3736     CONVERGENCE OBTAINED


    ADJUSTED NO-RAP EFF. =  99.4387
    MMD OF INLET SIZE DISTRIBUTION =  4.465E+01
    SIGMAP OF INLET SIZE DISTRIBUTION =  5.122E+00
    LOG-NORMAL GOODNESS OF FIT =  0.984
    MMD OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.044E+00
    SIGMAP OF EFFLUENT UNDER NO-RAP CONDITIONS =  2.230E+00
    LOG-NORMAL GOODNESS OF FIT =  0.997
    PRECIPITATION RATE PARAMETER UNDER NO-RAP CONDITIONS = 10.866


    SIGMAG=    0.250  WITH  0.100 SNEAKAGE OVER    3.000  STAGES
    NTEMP = 1
    RMMD =  6.00
    RSIGMA = 2.50
    CORR. EFF. =  99.1937
    CORRECTED MMD OF EFFLUENT =  2.924E+00
    CORRECTED SIGMAP OF EFFLUENT =  2.600E+00
    LOG-NORMAL GOODNESS OF FIT =  0.996
    CORRECTED PRECIPITATION RATE PARAMETER =   10.11
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UNADJUSTED MIGRATION VELOCITIES AND EFFICIENCIES, AND DISCRETE OUTLET MASS LOADINGS

IDEAL UNADJUSTED   IDEAL UNADJUSTED        NO-RAP            RAPPING PUFF      NO-RAP+RAP PUFF      RAPPING PUFF     PARTICLE
MIG. VEL.(CM/SEC)    EFFICIENCY(%)   DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DM/DLOGD(MG/DSCM)  DISTRIBUTION(%)  DIAM.(M)
 2.702E+00            7.243E+01           3.769E-01          1.953E-02          3.964E-01          5.350E-02        2.000E-07
 2.814E+00            7.387E+01           7.997E+00          2.203E-01          8.217E+00          2.806E-01        4.000E-07
 3.377E+00            8.003E+01           2.275E+01          1.082E+00          2.304E+01          1.586E+00        7.000E-07
 4.223E+00            8.666E+01           2.635E+01          3.092E+00          2.944E+01          2.834E+00        1.100E-06
 5.296E+00            9.200E+01           3.774E+01          6.046E+00          4.328E+01          5.720E+00        1.600E-06
 7.223E+00            9.681E+01           4.697E+01          1.072E+01          5.769E+01          1.308E+01        2.500E-06
 9.331E+00            9.883E+01           3.667E+01          1.460E+01          5.128E+01          8.358E+00        3.500E-06
 1.149E+01            9.958E+01           2.712E+01          1.652E+01          4.364E+01          1.105E+01        4.500E-06
 1.485E+01            9.992E+01           1.565E+01          1.739E+01          3.304E+01          1.310E+01        6.000E-06
 2.075E+01            9.999E+01           1.130E+01          1.626E+01          2.756E+01          1.545E+01        8.500E-06
 3.398E+01            1.000E+02           5.667E+00          1.284E+01          1.851E+01          1.245E+01        1.250E-05
 5.402E+01            1.000E+02           3.282E-01          7.789E+00          8.118E+00          1.013E+01        2.000E-05
 7.407E+01            1.000E+02           1.695E-01          1.357E+01          1.374E+01          5.918E+00        2.750E-05
```

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**********************************************************************************************
*                                                                                            *
*                              SUMMARY TABLE OF ESP OPERATING                                *
*                               PARAMETERS AND PERFORMANCE                                   *
*                                                                                            *
*                                                                                            *
*                                  DATA SET NUMBER   2                                       *
*                                                                                            *
*         ESP PERFORMANCE:     EFFICIENCY =  99.1937 %     SCA =  4.769E+01 M**2/(M**3/SEC)  *
*                                                                                            *
*         ELECTRICAL CONDITIONS:     AVG. APPLIED VOLTAGE =  4.172E+04 V                     *
*                                                                                            *
*                                    AVG. CURRENT DENSITY =   17.12 NA/CM**2                 *
*                                                                                            *
*                                    RESISTIVITY =  5.000E+10 OHM-CM                         *
*                                                                                            *
*         SIZE DISTRIBUTIONS:     INLET MMD =  4.465E+01 UM     INLET SIGMAP =  5.122E+00    *
*                                                                                            *
*                                 OUTLET MMD =  2.024E+00 UM     OUTLET SIGMAP =  2.600E+00  *
*                                                                                            *
*         NONIDEAL PARAMETERS:     GAS SNEAKAGE FRACTION = 0.10 /SECTION     GAS VELOCITY SIGMAG = 0.25
*                                                                                            *
*                                  RAPPING MMD =  6.000E+00 UM     RAPPING SIGMAP =  2.500E+00
*                                                                                            *
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STOP  011111
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APPENDIX O

DEFINITION OF VARIABLES USED IN THE PROGRAM

LIST OF VARIABLES, DEFINITIONS, AND UNITS FOR THE MAIN PROGRAM OF THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

NWIRE - Number of wires per electrical section per gas passage in a particular electrical section

LTHICK - Thickness of the collected particulate layer in a particular increment of length (mm/min)

JPART - Current density due to particles in a particular increment of length (A/m^2)

JION - Current density due to ions in a particular increment of length (A/m^2)

LINC - Length of the increments taken in a particular linear electrical section (m)

NWS(I) - Number of wires per electrical section per gas passage for the different linear electrical sections

LINCS(I) - Lengths of the increments taken in the different linear electrical sections (ft)

VISKIP - Indicator which determines whether or not a dirty-gas voltage-current curve is calculated in each increment of length

VISAME - Indicator which determines whether or not a clean-gas voltage-current curve is calculated for each of the electrical sections or just the first electrical section

CHKSUM(K) - Fractional increase in charge from one increment to the next for the different particle sizes

DIAM(K) - Diameters of the different particle sizes (µm and m)

ONO(K) - Initial number of particles per cubic meter of gas in each particle size band (#/m^3)

DXS(K) - Total number of particles removed per cubic meter of gas in each particle size band under ideal conditions and with no empirical corrections (#/m^3)

XMV(K) - Effective migration velocities for the different particle sizes under ideal conditions and with no empirical corrections (m/sec)

PCNT(K) - Percentage or fraction by mass in the inlet particle size distribution of the different size bands (% and decimal)

RAD(K) - Radii of the different particle sizes (m)

CCF(K) - Cunningham correction factor for the different particle sizes

PRCU(L) - Cumulative percent by mass up to each particle size in the inlet particle size distribution (%)

LSECT(I) - Number of length increments in the different linear electrical sections

PS(I) - Gas pressure in the different electrical sections (atm)

VG - Gas volume flow rate in a particular electrical section (m^3/sec)

ATOTAL - Total collection plate area of the precipitator (m^2)

DD - Mass density of the particles (kg/m^3)

ETAO - Estimated or design overall mass collection efficiency (%)

DL - Inlet mass loading (grains/ft^3 and kg/m^3)

PL - Total electrical length of the precipitator (ft and m)

RHO - Resistivity of the collected particulate layer (ohm-cm and ohm-m)

NS - Number of different particle size bands in the inlet particle size distribution

ZMMDI - Specified or fitted mass median diameter of the inlet particle size distribution based on a log-normal distribution (μm)

SIGMI - Specified or fitted geometric standard deviation of the inlet particle size distribution based on a log-normal distribution

NONID - Number of nonideal conditions of gas velocity nonuniformity and gas sneakage and/or particle reentrainment without rapping to be considered

NRAPD - Number of rapping puff particle size distributions to be considered

TDK - Temperature of the gas in a given electrical section (°K)

NUMSEC - Number of linear electrical sections in the precipitator

NEFF - Indicator which determines whether the unadjusted, ideal or adjusted, no-rap efficiency is used to determine the mass reentrained due to rapping

NTEMP - Indicator which specifies whether the precipitator is cold or hot side

GFIT - Linear-correlation coefficient obtained in the lognormal fit of the inlet particle size distribution

VOL(K) - Total volume of particles per cubic meter of gas in the different size bands (m^3/m^3(gas))

XNO(K) - Number of particles per cubic meter of gas in each size band at the start of each increment ($\#/m^3$)

Q(K) - Charge on each particle size at the end of a particular increment (coul)

WS(K) - Total weight of material per cubic meter of gas removed in each size band in a particular increment (kg/m^3)

ITL(M) - Identifying label for the calculations

DW(J) - Amount of material removed per increment on a total weight basis (kg)

AS(I) - Collection plate areas for the different linear electrical sections (m^2)

VOS(I) - Applied voltages for the different linear electrical sections (V)

TCS(I) - Total current for the different linear electrical sections (A)

WLS(I) - Total wire length for the different linear electrical sections (ft^2)

ACS(I) - Corona wire radii for the different linear electrical sections (in.)

BS(I) - Wire-to-plate spacing for the different linear electrical sections (in.)

SYS(I) - One-half the wire-to-wire spacing for the different linear electrical sections (in.)

VGS(I) - Gas volume flow rate for the different linear electrical sections (ft^3/min)

VGASS(I) - Gas velocity for the different linear electrical sections (ft/sec)

TEMPS(I) - Gas temperature for the different linear electrical sections (°F)

VISS(I) - Gas viscosity for the different linear electrical sections (kg/m-sec)

QSAT(K) - Saturation charge for the different particle sizes (coul)

U - Ion mobility adjusted for temperature and pressure (m^2/V-sec)

E - Elementary charge unit (coul)

EPSO - Permittivity of free space (coul^2/nt-m^2)

PI - Value of the constant π

ERAVG - Average electric field used for particle charging (V/m)

BC - Boltzmann's constant (J/°K)

TEMP - Gas temperature in a particular linear electrical section (°R)

EPS - Relative dielectric constant of the particles

VAVC - Root mean square velocity of the ions (m/sec)

OLDQ(K) - Charge on the different particle sizes in the increment prior to the one under consideration (coul)

OLDXNO(K) - Number of particles per cubic meter of gas in each size band at the start of the increment prior to the one under consideration (#/m^3)

RFS(I) - Roughness factor for the corona wires in the different linear electrical sections

START1(I) - Specified initial current density at which the calculation of a voltage-current curve starts in a given electrical section and the initial current density increment size (A/m^2)

START2(I) - Specified increment in current density which is used in place of START1(I) when the JI1-th point on the voltage-current curve is reached (A/m^2)

START3(I) - Specified increment in current density which is used in place of START2(I) when the JI2-th point on the voltage-current curve is reached (A/m^2)

VSTAR(I) - Estimate of the applied voltage corresponding to the first point on the voltage-current curve as defined by START1(I) (V)

XDC(J,K) - Charge on each particle size at the end of each increment (coul)

EAVG(N) - Average electric fields for particle charging in subincremental lengths (V/m)

CHFID(N) - Average free ion densities for particle charging in subincremental lengths (#/m^3)

ECOLL(N) - Average electric fields at the plate in subincremental lengths (V/m)

ECLEAN(N) - Average electric fields at the plate for clean gas in subincremental lengths (V/m)

ENDPT(L) - Particle diameters in the inlet cumulative percent by mass distribution (µm and m)

NENDPT - Number of particle diameters in the inlet cumulative percent by mass distribution

ARD50(II) - Rapping puff mass median diameters (µm)

ARSIGM(II) - Rapping puff geometric standard deviations

ASNUCK(JJ) - Fractions of gas sneakage and/or particle reentrainment without rapping

AZNUMS(JJ) - Number of stages over which gas sneakage and/or particle reentrainment without rapping occur

AZIGGY(JJ) - Normalized standard deviations of the gas velocity distribution

VCOOP(KK,LL) - Values at different grid points of the electric potential in a wire-plate geometry under conditions of no space charge (V)

TMFP - Ionic mean free path multiplied by a factor (m)

NVI - Indicator which specifies whether to base the electrical calculation on known voltages and currents or on calculated voltage-current characteristics

NPRINT - Indicator which designates when to print certain sectionalized data

NSECT - Indicator which keeps track of which electrical section the calculation is in

SLNGTH - Length of a particular electrical section (m)

A - Collection plate area of a particular linear electrical section (m^2)

VO - Applied voltage in a particular linear electrical section (V)

TC - Total current in a particular linear electrical section (A)

B - Wire-to-plate spacing in a particular linear electrical section (m)

AC - Corona wire radius in a particular linear electrical section (m)

WL - Total wire length in a particular linear electrical section (m)

CL - Total current per length of corona wire in a particular linear electrical section (A/m)

CD - Average current density at the plate in a particular linear electrical section (A/m^2)

ET - Average electric field in the deposited particulate layer in a particular linear electrical section (V/m)

SY - One-half the wire-to-wire spacing in a particular linear electrical section (m)

VGAS - Gas velocity in a particular linear electrical section (m/sec)

P - Gas pressure in a particular linear electrical section (atm)

VIS - Gas viscosity in a particular linear electrical section (kg/m-sec)

W - Total weight of particles per second passing into a particular linear electrical section (kg/sec)

XPI - Overall mass collection efficiency per increment based on the estimated or design efficiency (%)

RIOVR - Ratio of the ionic space charge density to the total space charge density

EPLT - Absolute value of the average electric field at the plate in a particular length increment (V/m)

AFID - Average reduced free ion density for particle charging in a particular length increment (#/m^3)

XCD - Average current density at the plate in a particular length increment (nA/cm^2)

ZMD - Interpolated mass median diameter of the collected particulate layer (m)

WT - Total weight of material per cubic meter of gas removed in all particle size bands in a given length increment (kg/m^3)

I - Index which runs over the different incremental lengths in its major usage

ROVRI - Ratio of the total space charge density to the ionic space charge density

NCALC - Indicator which determines whether to use equation (12)* for particle charging or the sum of the classical field and diffusion charges

NI - Number of subincremental lengths into which the incremental length is divided

VRATIO - Ratio of the peak applied voltage to the average for use in particle charging

NF - Number of increments taken along the length of the precipitator

NREAD - Indicator which specifies the unit number of the input device for reading data into the program

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*Equation numbers which are superscripted by this symbol refer to equations contained in reference 2.

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

SCOREF - Overall mass collection efficiency under no-rap + rap conditions (%)

CZMDL - Fitted log-normal mass median diameter of the outlet particle size distribution under no-rap + rap conditions (μm)

CSIGMO - Fitted log-normal geometric standard deviation of the outlet particle size distribution under no-rap + rap conditions

NRUN - Indicator that specifies which set of nonideal conditions is under consideration

SNUCK - Particular value of ASNUCK(JJ)

ZIGGY - Particular value of AZIGGY(JJ)

RMMD - Particular value of ARD50(II)[μm]

RSIGMA - Particular value of ARSIGM(II)

LK - Indicator which determines whether or not the input data are printed at a certain location in the program

DV - Total volume per cubic meter of gas occupied by particles [m^3(particles)/m^3(gas)]

NN - Number of increments in the Runge-Kutta integration of equation (12)*

NUMINC - Number of increments in the Simpson's Rule integration over Θ in equation (12)*

NX - Number of grid points in the x-direction for the numerical calculations of electrical conditions

NY - Number of grid points in the y-direction for the numerical calculations of electrical conditions

NDATA - Indicator which determines the type of data set that is to be read into the program

NEST - Indicator which specifies whether to use extensive calculations or estimation procedures in determining precipitator performance

NDIST - Indicator which specifies whether the user is to supply the inlet particle size distribution or the program is to calculate a log-normal distribution

NITER - Indicator which determines the maximum number of iterations over a loop that converges on overall mass efficiency or the number of iterations that will be performed over each incremental length of the precipitator in order to obtain self-consistent solutions for the electrical conditions

IFINAL - Indicator which causes the calculation of successive points on the voltage-current curve to cease after IFINAL points

JI1 - Indicator which allows the initial increment size on current density in the calculation of the voltage-current curve to be changed after JI1-1 points are determined on the curve

JI2 - Indicator which allows the second increment size on current density in the calculation of the voltage-current curve to be changed after JI2-1 points are determined on the curve

US - Ion mobility at standard temperature and pressure (reduced ion mobility)

FPATH - Factor which scales the ion mean free path

EBD - Electrical breakdown strength of the gas near the collection electrode or the collected particulate layer (V/m)

NDSET - Counter which keeps track of the number of the particular set of nonideal conditions which is under consideration

D50 - Same as ZMMDI (μm)

SIGMAP - Same as SIGMI

SCHARG - Saturation charge number from the field charging equation

CHRFID - Average free ion density for particle charging ($\#/m^3$)

TIMEI - Initial value of time for particle charging (sec)

TIMEF - Final value of time for particle charging (sec)

V - Value of the quantity $[e^2/4\pi\varepsilon_0 akT]$ found in equation (12)*

FACTRE - Value of the quantity $[\pi\tilde{v}a^2/2]$ found in equation (12)* $[m^3/sec]$

RSIZE - Radius of a particular particle (m)

CNUMBR - Charge number of a particular particle at time TIMEF

J - Index which runs over different particle size bands

II - Index which runs over subincremental lengths

ITER - Counter which keeps track of the number of iterations which is limited by NITER

OLDQF(K) - Value of field charge on the different particle sizes at the end of a given increment or subincrement (coul)

OLDQT(K) - Value of diffusion charge on the different particle sizes at the end of a given increment or subincrement (coul)

SOLDQF(K) - Value of field charge on the different particle sizes at the start of an increment which must be saved for the iteration procedure over subincrements in a given increment (coul)

SOLDQT(K) - Value of diffusion charge on the different particle sizes at the start of an increment which must be saved for the iteration procedure over subincrements in a given increment (coul)

CMKS - Value of the quantity $[4\pi\varepsilon_0]$ found in equation (12)* $[\mathrm{coul}^2/\mathrm{nt}\text{-}\mathrm{m}^2]$

KA - Index which runs over the different linear electrical sections

ZWT - Total weight of material per cubic meter of gas removed up to a given increment $(\mathrm{kg/m}^3)$

RATIO - Value of the quantity $[(K-1)/(K+2)]$ found in the particle charging equations

G - Value of the quantity $[K+2]$ found in the particle charging equations

INDEX - Indicator which keeps track of how many increments the calculation is into a particular linear electrical section

NCOOP - Indicator which allows certain calculations to be made only at the start of a new linear electrical section

SX - Wire-to-plate spacing in a particular linear electrical section (m)

RF - Roughness factor for the discharge wires in a particular linear electrical section

START - Particular value of START1(I) [A/m^2]

DSTART - Particular value of START2(I) [A/m^2]

CSTART - Particular value of START3(I) [A/m^2]

VSTART - Particular value of VSTAR(I) [V]

ZMFP - Ionic mean free path (m)

VAVG - Root mean square velocity of the ions (cm/sec)

VC - Value of the quantity [e^2/kT] found in the charging equations (coul/V)

FACTRC - Value of the quantity [$\pi\tilde{v}/2$] found in the charging equations (m/sec)

COEFFC - Value of the quantity [$e\pi b$] found in the charging equations (coul-m^2/V-sec)

TINC - Time interval for the gas to travel one increment (sec)

DTINC - Time interval for the gas to travel one subincrement (sec)

L - Index which runs over the different particle size bands

R - Value of the quantity [$eE_0/kT(K+2)$] found in equation (12)* [m^{-1}]

RR - Value of the quantity [eE_0/kT] found in equation (12)* [m^{-1}]

RG - Same as RR

VW - Operating applied voltage corresponding to a specified current density (V)

UEQ - Effective charge carrier mobility (m^2/V-sec)

NEC - Indicator which determines whether or not the average current density, average electric field, and average electric field at the plate are to be calculated in the subincremental lengths

AEPLT - Average electric field at the plate in a particular increment (V/m)

ACDNTY - Average current density at the plate in a particular increment (A/m^2)

NZ - Index which runs over subincremental lengths

CDCLN - Average current density at the plate when the gas is clean (A/m^2)

USUM - Sum of effective charge carrier mobilities over the subincremental lengths in a particular incremental length (m^2/V-sec)

WSSUM - Total weight of material per cubic meter of gas removed in a particular size band in a particular subincrement (kg/m^3)

RHOSUM - Sum of the ratio of the ionic space charge to the total space charge over the subincremental lengths in a particular incremental length

SW - Cumulative sum of estimated amount of material removed per second in successive length increments (kg/sec)

OROVRI - Ratio of total charge density to ionic charge density in increment prior to the one the calculation is in

XS - Computed value of the exponential argument in the Deutsch equation for the estimated or design overall mass collection efficiency

ETAPF - Overall mass collection fraction per increment based on the estimated or design efficiency

FID - Average free ion density (#/m^3)

AVGFID - Average reduced free ion density for particle charging (#/cm^3)

PROT - Total charge density due to particles that remain after passing through a given increment (coul/m^3)

SERAVG - Average electric field in a particular increment (V/m).

XIPC - Initial value of charge number on a given particle size at the start of a new increment

H - Increment size for the Runge-Kutta integration of equation (12)* [sec]

DCONST - Value of the quantity $[(K-1)a^3/(K+2)]$ found in equation (12)* $[m^3]$

CONST - Value of the quantity $[2(K-1)a^3E_0/(K+2)]$ found in equation (12)* $[V\text{-}m^2]$

S - Value of the quantity [3a] found in equation (12)* [m]

ECONST - Value of the quantity $[3eE_0a/kT(K+2)]$ found in equation (12)*

FCONST - Value of the quantity $[(K-1)eE_0a^3/kT(K+2)]$ found in equation (12)* $[m^2]$

COEFF - Value of the quantity $[bqs/4\varepsilon_0]$ found in equation (12)* $[m^3/sec]$

CTIME - Time at the end of a given increment (sec)

EMV(K) - Unadjusted, ideal migration velocities for the different particle sizes in a given increment (m/sec)

X - Exponent used in the Deutsch equation to determine the unadjusted, ideal collection fractions for the different particle sizes in a given increment

EFF - Unadjusted, ideal collection fraction for a given particle size band in a given increment

DXNO - Number of particles per cubic meter of gas removed from a given particle size band in a given increment $(\#/m^3)$

DNSION - Ion density in the absence of particles $(\#/m^3)$

DELTNP - Number density of charges transferred from ions to particles in a given subincremental length $(\#/m^3)$

SUMMOB - Weighted summation of particle mobilities $(m^2/V\text{-}sec/m^3)$

PNUM - Total number of particles per unit volume of gas entering a given subincremental length $(\#/m^3)$

RHOP - Total average particulate charge density in a given subincremental length $(coul/m^3)$

TCHRG - Average particle charge density for a given particle size in a given subincremental length $(coul/m^3)$

PMOB - Weighted particulate mobility in a given subincremental length (m^2/V-sec)

TDNSP - Total average particulate charge number density in a given subincremental length (#/m^3)

RDNSI - Average reduced ion density in a given subincremental length (#/m^3)

SUMCD - Sum of the average current densities at the plate from the different increments in a particular linear electrical section (A/m^2)

SUMVO - Sum of the applied voltages from the different increments in a particular linear electrical section (V)

SKIP - Electric field at the plate in the increment prior to the one the calculation is in (V/m)

SIGMA - Difference between the ratio of the total space charge density to the ionic space charge density in the (I+1)-th and I-th increments

VERGE - Initial estimate of the space charge density at the corona wire to start the calculation of the electric field at the plate (coul/m^3)

CVERGE - Converged value of the space charge density at the wire in calculating the electric field at the plate (coul/m^3)

ZTM - Cumulative sum of the weight of material per cubic meter of gas collected up to a given particle size in a given increment (kg/m^3)

CZA - Ratio of the partial sum of the weight of dust removed per cubic meter of gas up the K-th particle size in a given increment to the total weight of dust removed per cubic meter of gas in a given increment

CZB - Ratio of the partial sum of the weight of dust removed per cubic meter of gas up to the (K-1)-th particle size in a given increment to the total weight of dust removed per cubic meter of gas in a given increment

TL1 - Difference between CZA and CZB for use in interpolating to find the mass median diameter of the collected dust

TL2 - Difference between 0.50 and CZB for use in interpolating to find the mass median diameter of the collected dust

KJ - Index which runs simultaneously with the index which runs over the different particle sizes and keeps track of the (K-1)-th particle size

ETC - Ideal, unadjusted overall mass collection efficiency for the entire precipitator (%)

DIFF - Difference between the calculated ideal, unadjusted overall mass collection efficiency and the estimated value

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE PRTINP USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

LK - Indicator which determines whether or not the input data are printed at a certain location in the program

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

NDSET - Counter which keeps track of the number of the particular set of nonideal conditions which is under consideration

DL - Inlet mass loading (kg/m^3)

DLB - Inlet mass loading (grains/ft^3)

PL - Total electrical length of the precipitator (m)

PLB - Total electrical length of the precipitator (ft)

RHO - Resistivity of the collected particulate layer (ohm-m)

RHOCGS - Resistivity of the collected particulate layer (ohm-cm)

NCARD - Counter which keeps track of the number of each successive imput data card

NENDPT - Number of particle diameters in the inlet cumulative percent by mass distribution

NDATA - Indicator which determines the type of data set that is to be read into the program

ITL(M) - Identifying label for the calculations

NEST - Indicator which specifies whether to use extensive calculations or estimation procedures in determining precipitator performance

NDIST - Indicator which specifies whether the user is to supply the inlet particle size distribution or the program is to calculate a log-normal distribution

NVI - Indicator which specifies whether to base the electrical calculation on known voltages and currents or on calculated voltage-current characteristics

NX - Number of grid points in the x-direction for the numerical calculations of electrical conditions

NY - Number of grid points in the y-direction for the numerical calculations of electrical conditions

NITER - Indicator which determines the maximum number of iterations over a loop that converges on overall mass efficiency or the number of iterations that will be performed over each incremental length of the precipitator in order to obtain self-consistent solutions for the electrical conditions

NCALC - Indicator which determines whether to use equation (12)* for particle charging or the sum of the classical field and diffusion charges

NRAPD - Number of rapping puff particle size distributions to be considered

NEFF - Indicator which determines whether the unadjusted, ideal or adjusted, no-rap efficiency is used to determine the mass reentrained due to rapping

NTEMP - Indicator which specifies whether the precipitator is cold or hot side

NONID - Number of nonideal conditions of gas velocity nonuniformity and gas sneakage and/or particle reentrainment without rapping to be considered

NN - Number of increments in the Runge-Kutta integration of equation (12)*

NUMINC - Number of increments in the Simpson's Rule integration over θ in equation (12)*

IFINAL - Indicator which causes the calculation of successive points on the voltage-current curve to cease after IFINAL points

JI1 - Indicator which allows the initial increment size on current density in the calculation of the voltage-current curve to be changed after JI1-1 points are determined on the curve

JI2 - Indicator which allows the second increment size on current density in the calculation of the voltage-current curve to be changed after JI2-1 points are determined on the curve

VISKIP - Indicator which determines whether or not a dirty-gas voltage-current curve is calculated in each increment of length

VISAME - Indicator which determines whether or not a clean-gas voltage-current curve is calculated for each of the electrical sections or just the first electrical section

ETAO - Estimated or design overall mass collection efficiency (%)

DD - Mass density of the particles (kg/m^3)

EPS - Relative dielectric constant of the particles

VRATIO - Ratio of the peak applied voltage to the average for use in particle charging

US - Ion mobility at standard temperature and pressure (reduced ion mobility)

FPATH - Factor which scales the ion mean free path

EBD - Electrical breakdown strength of the gas near the collection electrode or the collected particulate layer (V/m)

ARD50(II) - Rapping puff mass median diameters (μm)

ARSIGM(II) - Rapping puff geometric standard deviations

ASNUCK(JJ) - Fractions of gas sneakage and/or particle reentrainment without rapping

AZIGGY(JJ) - Normalized standard deviations of the gas velocity distribution

AZNUMS(JJ) - Number of stages over which gas sneakage and/or particle reentrainment without rapping occur

NDCARD - Indicator which determines how the arrays ENDPT(L) and PRCU(L) should be printed

ENDPT(L) - Particle diameters in the inlet cumulative percent by mass distribution (μm and m)

D50 - Specified or fitted mass median diameter of the inlet particle size distribution based on a log-normal distribution (μm)

SIGMAP - Specified or fitted geometric standard deviation of the inlet particle size distribution based on a log-normal distribution

PRCU(L) - Cumulative percent by mass up to each particle size in the inlet particle size distribution (%)

NUMSEC - Number of linear electrical sections in the precipitator

LSECT(I) - Number of length increments in the different linear electrical sections

AS(I) - Collection plate areas for the different linear electrical sections (m^2)

VOS(I) - Applied voltages for the different linear electrical sections (V)

TCS(I) - Total current for the different linear electrical sections (A)

WLS(I) - Total wire length for the different linear electrical sections (ft^2)

ACS(I) - Corona wire radii for the different linear electrical sections (in.)

BS(I) - Wire-to-plate spacing for the different linear electrical sections (in.)

NWS(I) - Number of wires per electrical section per gas passage for the different linear electrical sections

SYS(I) - One-half the wire-to-wire spacing for the different linear electrical sections (in.)

VGS(I) - Gas volume flow rate for the different linear electrical sections (ft^3/min)

VGASS(I) - Gas velocity for the different linear electrical sections (ft/sec)

TEMPS(I) - Gas temperature for the different linear electrical sections (°F)

PS(I) - Gas pressure in the different electrical sections (atm)

VISS(I) - Gas viscosity for the different linear electrical sections (kg/m-sec)

LINCS(I) - Lengths of the increments taken in the different linear electrical sections (ft)

RFS(I) - Roughness factor for the corona wires in the different linear electrical sections

START1(I) - Specified initial current density at which the calculation of a voltage-current curve starts in a given electrical section and the initial current density increment size (A/m^2)

START2(I) - Specified increment in current density which is used in place of START1(I) when the JI1-th point on the voltage-current curve is reached (A/m^2)

START3(I) - Specified increment in current density which is used in place of START2(I) when the JI2-th point on the voltage-current curve is reached (A/m^2)

VSTAR(I) - Estimate of the applied voltage corresponding to the first point on the voltage-current curve as defined by START1(I) (V)

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE SPCHG1 USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

I - Index which runs over the incremental lengths

SW - Cumulative sum of estimated amount of material removed per second in successive length increments (kg/sec)

ROVRI - Ratio of the total space charge density to the ionic space charge density

OROVRI - Ratio of total charge density to ionic charge density in increment prior to the one the calculation is in

ETAO - Estimated overall mass collection efficiency (%)

XS - Computed value of the exponential argument in the Deutsch equation for the estimated overall mass collection efficiency

LINC - Length of the increments taken in a particular linear electrical section (m)

PL - Total electrical length of the precipitator (m)

ETAPF - Overall mass collection fraction per increment based on the estimated efficiency

W - Total weight of particles per second passing into a particular linear electrical section (kg/sec)

DW(J) - Amount of material removed per increment on a total weight basis (kg)

CD - Average current density at the plate in a particular linear electrical section (A/m^2)

E - Elementary charge unit (coul)

U - Ion mobility adjusted for temperature and pressure (m^2/V-sec)

ERAVG - Average electric field used for particle charging (V/m)

FID - Average free ion density (#/m^3)

SUM - Total particulate charge density in a given increment based on saturation charges (coul/m^3)

NS - Number of different particle size bands in the inlet particle size distribution

L - Index which runs over the different particle size bands

QSAT(L) - Saturation charge for the different particle sizes (coul)

XNO(L) - Number of particles per cubic meter of gas in each size band at the start of each increment (#/m^3)

LSECT(I) - Number of length increments in the different linear electrical sections

NSECT - Indicator which keeps track of which electrical section the calculation is in

TC - Total current in a particular linear electrical section (A)

VG - Gas volume flow rate in a particular electrical section (m^3/sec)

ZC - Ratio of the particulate charge density to the ionic charge density (ratio of 200 times the particulate current to the total current)

AFID - Average reduced free ion density for particle charging in a particular length increment (#/m^3)

AVGFID - Average reduced free ion density for particle charging (#/cm^3)

XCD - Average current density at the plate in a particular length increment (nA/cm^2)

UEQ - Effective charge carrier mobility (m^2/V-sec)

XPI - Overall mass collection efficiency per increment based on the estimated efficiency (%)

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE SPCHG2 USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

I - Index which runs over the incremental lengths

ETAO - Design overall mass collection efficiency (%)

XS - Computed value of the exponential argument in the Deutsch equation for the design overall mass collection efficiency

LINC - Length of the increments taken in a particular linear electrical section (m)

PL - Total electrical length of the precipitator (m)

ETAPF - Overall mass collection fraction per increment based on the design efficiency

DELTNP - Number density of charges transferred from ions to particles in a given subincremental length (#/m^3)

SUMMOB - Weighted summation of particle mobilities (m^2/V-sec/m^3)

PNUM - Total number of particles per unit volume of gas entering a given subincremental length (#/m^3)

RHOP - Total average particulate charge density in a given subincremental length (coul/m^3)

J - Index which runs over the different particle size bands

XNO(J) - Number of particles per cubic meter of gas in each size band at the start of each increment (#/m^3)

XDC(I,J) - Charge on each particle size at the end of each increment (coul)

TCHRG - Average particle charge density for a given particle size in a given subincremental length (coul/m^3)

CCF(J) - Cunningham correction factor for the different particle sizes

VIS - Gas viscosity in a particular linear electrical section (kg/m-sec)

RAD(J) - Radii of the different particle sizes (m)

DIFF - Difference between the charge on a given particle size in the (I+1)-th and I-th increments (coul)

II - Index which runs over the subincremental lengths

Q(J) - Charge on each particle size at the end of a particular increment (coul)

OLDQ(J) - Charge on the different particle sizes in the increment prior to the one under consideration (coul)

PMOB - Weighted particulate mobility in a given subincremental length (m^2/V-sec)

TDNSP - Total average particulate charge number density in a given subincremental length (#/m^3)

CHFID(II) - Average free ion densities for particle charging in subincremental lengths (#/m^3)

DNSION - Ion density in the absence of particles (#/m^3)

RDNSI - Average reduced ion density in a given subincremental length (#/m^3)

PIR - Ratio of the total charge density which can be accepted by particles in a given subincrement to the available free ion density

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

AFID - Average reduced free ion density for particle charging in a particular length increment (#/m^3)

AVGFID - Average reduced free ion density for particle charging (#/cm^3)

U - Ion mobility adjusted for temperature and pressure (m^2/V-sec)

E - Elementary charge unit (coul)

UEQ - Effective charge carrier mobility (m^2/V-sec)

RIOVR - Ratio of the ionic space charge density to the total space charge density

XPI - Overall mass collection efficiency per increment based on the design efficiency (%)

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE EFLD1 USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

VO - Applied voltage (negative value used in calculations) [V]

PI - Value of the constant π

EPSO - Permittivity of free space (coul^2/nt-m^2)

AC - Radius of the corona wires (m)

RO - Radius of the corona wires (m)

ROC - Radius of the corona wires (cm)

RF - Roughness factor for the corona wires

TDK - Temperature of the gas stream (°K)

P - Pressure in the gas stream (atm)

RELD - Relative air density [$\delta = (T_0/T)(P/P_0)$]

EORO - Product of the corona starting electric field and the wire radius

CD - Average current density at the plate (A/m^2)

UEQ - Effective charge carrier mobility (m^2/V-sec)

VERGE - Initial estimate of the space charge density at the corona wire to start the calculation of the electric field at the plate (coul/m^3)

QZERO - Space charge density at the corona wire (coul/m^3)

I - Index which runs over grid points in the x-direction

NX - Number of grid points in the x-direction for the numerical calculations of electrical conditions

J - Index which runs over grid points in the y-direction

NY - Number of grid points in the y-direction for the numerical calculations of electrical conditions

MOBILT(I,J) - Array containing the values of effective charge carrier mobility at the different grid points (m^2/V-sec)

MAXJ - Upper limit that the calculated average current density at the plate cannot exceed (A/m^2)

MINJ - Lower limit that the calculated average current density at the plate cannot fall below (A/m^2)

NX1 - Number of grid intervals in the x-direction for the numerical calculations of electrical conditions

NY1 - Number of grid intervals in the y-direction for the numerical calculations of electrical conditions

SX - Wire-to-plate spacing in a particular linear electrical section (m)

AX - Interval size in the x-direction (m)

SY - One-half the wire-to-wire spacing in a particular linear electrical section (m)

AY - Interval size in the y-direction (m)

AXS - Value of the quantity $[a_x^2]$ (m^2)

AYS - Value of the quantity $[a_y^2]$ (m^2)

ASP - Value of the quantity $[(a_x^2+a_y^2)/\varepsilon_0]$ (m^4-nt/coul^2)

ASS - Value of the quantity $[1/2(a_x^2+a_y^2)]$ (m^{-2})

Z - Counter which keeps track of the number of times the calculation iterates due to lack of convergence in the average current density at the plate

VCOOP(I,J) - Array containing the values of electric potential given equation (26)* at the different grid points (V)

V(I,J) - Array containing the value of the electric potential at each point in the grid during an iteration (V)

IZ - Same as Z

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

LL - Counter which keeps track of the number of times the calculation iterates due to lack of convergence in the electric potential at each point in the grid

RHO(I,J) - Array containing the value of the space charge density at each point in the grid during an iteration (coul/m^3)

EX(I,J) - Array containing the value of the component of the electric field intensity perpendicular to the plates at each point in the grid during an iteration (V/m)

EY(I,J) - Array containing the value of the component of the electric field intensity parallel to the plates at each point in the grid during an iteration (V/m)

Q1 - Value of the quantity $[2b_{i,1}]$ along the line AD where $b_{i,j}$ is the effective charge carrier mobility which is a function of position (m^2/V-sec)

Q2 - Value of the quantity $[2b_{i,1}a_x]$ along the line AD (m^3/V-sec)

Q3 - Value of the quantity $[2b_{i,1}a_y]$ along the line AD (m^3/V-sec)

Q4 - Value of the quantity $[2b_{i,1}a_x a_y]$ along the line AD (m^4/V-sec)

Q5 - Value of the quantity $[-\varepsilon_0 E_x(2b_{i,1}a_y - a_y b_{i-1,1})]$ along the line AD ($coul^2$/nt-sec)

Q6 - Value of the quantity $[\varepsilon_0{}^2 E_x{}^2(2b_{i,1}a_y - a_y b_{i-1,1})^2]$ along the line AD ($coul^4/nt^2-sec^2$)

Q7 - Value of the quantity $[4b_{i,1}^2 a_x a_y{}^2 \varepsilon_0 E_x \rho_{i-1,1}]$ along the line AD where $\rho_{i,j}$ is the space charge density at the different grid points ($coul^2-m^2/V^2-sec^2$)

Q8 - Value of the quantity $[-\sqrt{Q6+Q7}]$ along the line AD (coul-m/V-sec)

P1 - Value of the quantity $[2b_{i,j}]$ along the line AB (m^2/V-sec)

P2 - Value of the quantity $[2b_{i,j}a_x]$ along the line AB (m^3/V-sec)

P3 - Value of the quantity $[2b_{1,j}a_y]$ along the line AB (m^3/V-sec)

P4 - Value of the quantity $[2b_{1,j}a_x a_y]$ along the line AB (m^4/V-sec)

P5 - Value of the quantity $[-\varepsilon_0 E_y(2b_{1,j}a_x - a_x b_{1,j-1})]$ along the line AB ($coul^2$/nt-sec)

P6 - Value of the quantity $[\varepsilon_0{}^2 E_y{}^2(2b_{1,j}a_x - a_x b_{1,j-1})^2]$ along the line AB ($coul^4/nt^2-sec^2$)

P7 - Value of the quantity $[4b^2_{1,j}a_x{}^2 a_y \varepsilon_0 E_y \rho_{1,j-1}]$ along the line AB ($coul^2-m^2/V^2-sec^2$)

P8 - Value of the quantity $[-\sqrt{P6+P7}]$ along the line AB (coul-m/V-sec)

R1 - Value of the quantity $[2b_{i,NY}]$ along the line BC (m^2/V-sec)

R2 - Value of the quantity $[2b_{i,NY}a_x]$ along the line BC (m^3/V-sec)

R3 - Value of the quantity $[2b_{i,NY}a_y]$ along the line BC (m^3/V-sec)

R4 - Value of the quantity $[2b_{i,NY}a_x a_y]$ along the line BC (m^4/V-sec)

R5 - Value of the quantity $[-\varepsilon_0 E_x(2b_{i,NY}a_y - a_y b_{i-1,NY})]$ along the line BC ($coul^2$/nt-sec)

R6 - Value of the quantity $[\varepsilon_0{}^2 E_x{}^2(2b_{i,NY}a_y - a_y b_{i-1,NY})]$ along the line BC ($coul^4/nt^2-sec^2$)

R7 - Value of the quantity $[4b^2_{i,NY}a_x a^2_y \varepsilon_0 E_x \rho_{i-1,NY}]$ along the line BC ($coul^2-m^2/V^2-sec^2$)

R8 - Value of the quantity $[-\sqrt{R6+R7}]$ along the line BC (coul-m/V-sec)

D1 - Value of the quantity $[2b_{i,j}]$ for interior points in the grid (m^2/V-sec)

D2 - Value of the quantity $[2a_x b_{i,j}]$ for interior points in the grid (m^3/V-sec)

D3 - Value of the quantity $[2a_y b_{i,j}]$ for interior points in the grid (m^3/V-sec)

D4 - Value of the quantity $[2a_x a_y b_{i,j}]$ for interior points in the grid (m^4/V-sec)

D5 - Value of the quantity $[-\varepsilon_0(E_x(2a_y b_{i,j} - a_y b_{i-1,j}) + E_y(2a_x b_{i,j} - a_x b_{i,j-1}))]$ for interior points in the grid ($coul^2$/nt-sec)

D6 - Value of the quantity [D5·D5] ($coul^4/nt^2-sec^2$)

D7 - Value of the quantity $[4b_{i,j}^2 a_x a_y \varepsilon_0(a_y E_x \rho_{i-1,j} + a_x E_y \rho_{i,j-1}))]$ for interior points in the grid ($coul^2-m^2/V^2-sec^2$)

D8 - Value of the quantity $[-\sqrt{D6+D7}]$ for interior points in the grid (coul-m/V-sec)

OLDV(I,J) - Array containing the value of the electric potential at each point in the grid during the previous iteration (V)

OLDRO(I,J) - Array containing the value of the space charge density at each point in the grid during the previous iteration ($coul/m^3$)

CDNSTY(I,J) - Array containing the value of current density at each point in the grid (A/m^2)

ACDNTY - Average current density at the plate (A/m^2)

EPLT - Sum of the values of the electric field intensity at the plate (V/m)

AEPLT - Average electric field at the plate (V/m)

CVERGE - Converged value of the space charge density at the wire in calculating the electric field at the plate ($coul/m^3$)

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE EFLD2 USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

IVCK - Indicator which terminates the calculation of points on the voltage-current whenever the specified applied voltage is reached and interpolated upon

VO - Specified operating applied voltage (V)

VSTART - Particular value of VSTAR(I) [V]

VW - Operating applied voltage corresponding to a specified current density (V)

AC - Radius of the corona wires (m)

RO - Radius of the corona wires (m)

TDK - Temperature of the gas stream (°K)

P - Pressure of the gas stream (atm)

RELD - Relative air density [$\delta = (T_0/T)(P/P_0)$]

ROC - Radius of the corona wires (cm)

RF - Roughness factor for the corona wires

EORO - Product of the corona starting electric field and the wire radius (V)

I - Index which runs over grid points in the x-direction

NX - Number of grid points in the x-direction for the numerical calculations of electrical conditions

J - Index which runs over grid points in the y-direction

NY - Number of grid points in the y-direction for the numerical calculations of electrical conditions

UEQ - Effective charge carrier mobility (m^2/V-sec)

MOBILT(I,J) - Array containing the values of effective charge carrier mobility at the different grid points (m^2/V-sec)

PI - Value of the constant π

EPSO - Permittivity of free space ($coul^2/nt\text{-}m^2$)

START - Particular value of START1(I) [A/m^2]

SSTART - Initial value of START which is saved (A/m^2)

MINJ - Lower limit that the calculated average current density at the plate cannot fall below (A/m^2)

MAXS - Particular value of current density on the voltage-current curve (A/m^2)

NX1 - Number of grid intervals in the x-direction for the numerical calculations of electrical conditions

NY1 - Number of grid intervals in the y-direction for the numerical calculations of electrical conditions

SX - Wire-to-plate spacing in a particular linear electrical section (m)

AX - Interval size in the x-direction (m)

SY - One-half the wire-to-wire spacing in a particular linear electrical section

AY - Interval size in the y-direction (m)

AXS - Value of the quantity [$a_x{}^2$] (m^2)

AYS - Value of the quantity [$a_y{}^2$] (m^2)

ASP - Value of the quantity [$(a_x{}^2+a_y{}^2)/\varepsilon_0$] ($m^4\text{-}nt/coul^2$)

ASS - Value of the quantity [$1/2(a_x{}^2+a_y{}^2)$](m^{-2})

IFINAL - Indicator which causes the calculation of successive points on the voltage-current curve to cease after IFINAL points

II - Index which runs over the different current densities to be used on the voltage-current curve

JI1 - Indicator which allows the initial increment size on current density in the calculation of the voltage-current curve to be changed after JI1-1 points are determined on the curve

DSTART - Particular value of START2(I) $[A/m^2]$

JI2 - Indicator which allows the second increment size on current density in the calculation of the voltage-current curve to be changed after JI2-1 points are determined on the curve

CSTART - Particular value of START3(I) $[A/m^2]$

MAXJ - Upper limit that the calculated average current density at the plate cannot exceed (A/m^2)

QZERO - Space charge density at the corona wire $(coul/m^3)$

NWIRE - Number of wires per electrical section per gas passage in a particular electrical section

Z - Counter which keeps track of the number of times the calculation iterates due to lack of convergence in the average current density at the plate

VCOOP(I,J) - Array containing the values of electric potential given equation (26)* at the different grid points (V)

V(I,J) - Array containing the value of the electric potential at each point in the grid during an iteration (V)

IZ - Same as Z

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

LL - Counter which keeps track of the number of times the calculation iterates due to lack of convergence in the electric potential at each point in the grid

RHO(I,J) - Array containing the value of the space charge density at each point in the grid during an iteration $(coul/m^3)$

EX(I,J) - Array containing the value of the component of the electric field intensity perpendicular to the plates at each point in the grid during an iteration (V/m)

EY(I,J) - Array containing the value of the component of the electric field intensity parallel to the plates at each point in the grid during an iteration (V/m)

Q1 - Value of the quantity $[2b_{i,1}]$ along the line AD where $b_{i,j}$ is the effective charge carrier mobility which is a function of position (m^2/V-sec)

Q2 - Value of the quantity $[2b_{i,1}a_x]$ along the line AD (m^2/V-sec)

Q3 - Value of the quantity $[2b_{i,1}a_y]$ along the line AD (m^3/V-sec)

Q4 - Value of the quantity $[2b_{i,1}a_x a_y]$ along the line AD (m^4/V-sec)

Q5 - Value of the quantity $[-\varepsilon_0 E_x(2b_{i,1}a_y - a_y b_{i-1,1})]$ along the line AD ($coul^2$/nt-sec)

Q6 - Value of the quantity $[\varepsilon_0^2 E_x^2(2b_{i,1}a_y - a_y b_{i-1,1})^2]$ along the line AD ($coul^4/nt^2-sec^2$)

Q7 - Value of the quantity $[4b_{i,1}^2 a_x a_y^2 \varepsilon_0 E_x \rho_{i-1,1}]$ along the line AD where $\rho_{i,j}$ is the space charge density at the different grid points ($coul^2-m^2/V^2-sec^2$)

Q8 - Value of the quantity $[-\sqrt{Q6+Q7}]$ along the line AD (coul-m/V-sec)

P1 - Value of the quantity $[2b_{1,j}]$ along the line AB (m^2/V-sec)

P2 - Value of the quantity $[2b_{1,j}a_x]$ along the line AB (m^3/V-sec)

P3 - Value of the quantity $[2b_{1,j}a_y]$ along the line AB (m^3/V-sec)

P4 - Value of the quantity $[2b_{1,j}a_x a_y]$ along the line AB (m^4/V-sec)

P5 - Value of the quantity $[-\varepsilon_0 E_y(2b_{1,j}a_x - a_x b_{1,j-1})]$ along the line AB ($coul^2$/nt-sec)

P6 - Value of the quantity $[\varepsilon_0^2 E_y^2(2b_{1,j}a_x - a_x b_{1,j-1})^2]$ along the line AB ($coul^4/nt^2-sec^2$)

P7 - Value of the quantity $[4b_{1,j}^2 a_x^2 a_y \varepsilon_0 E_y \rho_{1,j-1}]$ along the line AB ($coul^2-m^2/V^2-sec^2$)

P8 - Value of the quantity $[-\sqrt{P6+P7}]$ along the line AB (coul-m/V-sec)

R1 - Value of the quantity $[2b_{i,NY}]$ along the line BC (m^2/V-sec)

R2 - Value of the quantity $[2b_{i,NY}a_x]$ along the line BC (m^3/V-sec)

R3 - Value of the quantity $[2b_{i,NY}a_y]$ along the line BC (m^3/V-sec)

R4 - Value of the quantity $[2b_{i,NY}a_x a_y]$ along the line BC (m^4/V-sec)

R5 - Value of the quantity $[-\varepsilon_0 E_x(2b_{i,NY}a_y - a_y b_{i-1,NY}]$ along the line BC ($coul^2$/nt-sec)

R6 - Value of the quantity $[\varepsilon_0{}^2 E_x^2(2b_{i,NY}a_y - a_y b_{i-1,NY}]$ along the line BC ($coul^4/nt^2-sec^2$)

R7 - Value of the quantity $[4b_{i,NY}^2 a_x a_y^2 \varepsilon_0 E_x \rho_{i-1,NY}]$ along the line BC ($coul^2-m^2/V^2-sec^2$)

R8 - Value of the quantity $[-\sqrt{R6+R7}]$ along the line BC (coul-m/V-sec)

D1 - Value of the quantity $[2b_{i,j}]$ for interior points in the grid (m^2/V-sec)

D2 - Value of the quantity $[2a_x b_{i,j}]$ for interior points in the grid (m^3/V-sec)

D3 - Value of the quantity $[2a_y b_{i,j}]$ for interior points in the grid (m^3/V-sec)

D4 - Value of the quantity $[2a_x a_y b_{i,j}]$ for interior points in the grid (m^4/V-sec)

D5 - Value of the quantity $[-\varepsilon_0(E_x(2a_y b_{i,j} - a_y b_{i-1,j}) + E_y(2a_x b_{i,j} - a_x b_{i,j-1}))]$ for interior points in the grid ($coul^2$/nt-sec)

D6 - Value of the quantity $[D5 \cdot D5]$ ($coul^4/nt^2-sec^2$)

D7 - Value of the quantity $[4b_{i,j}^2 a_x a_y \varepsilon_0(a_y E_x \rho_{i-1,j} + a_x E_y \rho_{i,j-1})]$ for interior points in the grid ($coul^2-m^2/V^2-sec^2$)

D8 - Value of the quantity $[-\sqrt{D6+D7}]$ for interior points in the grid (coul-m/V-sec)

OLDV(I,J) - Array containing the value of the electric potential at each point in the grid during the previous iteration (V)

OLDRO(I,J) - Array containing the value of the space charge density at each point in the grid during the previous iteration (coul/m^3)

CDNSTY(I,J) - Array containing the value of current density at each point in the grid (A/m^2)

ACDNTY - Average current density at the plate (A/m^2)

TEST - Absolute value of the difference between the calculated average current density at the plate and the specified value (A/m^2)

TEST1 - One percent of the calculated average current density at the plate (A/m^2)

EPLT - Sum of the values of the electric field intensity at the plate (V/m)

AEPLT - Average electric field at the plate (V/m)

EBD - Electrical breakdown strength of the gas near the collection electrode or the collected particulate layer (V/m)

OLDVW - The value of applied voltage at the point prior to the one under consideration (V)

OLDCD - The value of average current density at the plate at the point prior to the one under consideration (A/m^2)

NEC - Indicator which determines whether or not the average current density, average electric field, and average electric field at the plate are to be calculated in the subincremental lengths

K - Index which sequences the grid strips in the basic area for which the calculations are performed

RSUM - Average charge number density in a particular grid strip (#/m^3)

ESUM - Average electric field intensity in a particular grid strip (V/m)

EAVGS(K) - Array containing the average electric field intensities in the different grid strips in the basic area for which the calculations are performed (V/m)

CHFIDS(K) - Array containing the average charge number densities in the different grid strips in the basic area for which the calculations are performed (#/m^3)

NYY - Index which renumbers the grid strips so that by symmetry the area covered by the half-wire spacing which was not considered in the calculations can be taken into account

EAVG(L) - Array containing the average electric field intensities in the different grid strips which cover an area between successive wires (V/m)

CHFID(L) - Array containing the average charge number densities in the different grid strips which cover an area between successive wires (#/m^3)

L - Index which runs over and numbers the first (NY-1) grid strips in a given wire-to-wire spacing

KK - Index which runs over the different grid strips in the basic area for which the calculations are performed

M1 - Number of the first grid strip in the last (NY-1) grid strips in a given wire-to-wire spacing

M2 - Number of the last grid strip in a given wire-to-wire spacing

M - Index which runs over and numbers the last (NY-1) grid strips in a given wire-to-wire spacing

LL - Index which sequences the grid strips in the basic area for which the calculations are performed

NN - Index which runs over points in the y-direction

ECOLLS(LL) - Array containing the average electric field intensity at the plate in the different grid strips in the basic area for which the calculations are performed (V/m)

L1 - Index which renumbers the grid strips so that by symmetry the area covered by the half-wire spacing which was not considered in the calculations can be taken into account

ECOLL(L) - Array containing the average electric field intensity at the plate in the different grid strips which cover an area between successive wires (V/m)

L2 - Index which runs over the different grid strips in the basic area for which the calculations are performed

I1 - Number of the first grid strip in the last (NY-1) grid strips in a given wire-to-wire spacing

I2 - Number of the last grid strip in a given wire-to-wire spacing

I - Index which runs over and numbers the last (NY-1) grid strips in a given wire-to-wire spacing

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE CHARGN USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

H - Increment size used in the Runge-Kutta scheme (sec)

H2 - One-half the increment size chosen for the Runge-Kutta scheme (sec)

YI - Time at the start of a given increment or subincrement of the precipitator (sec)

Y - Time at the end of a given increment or subincrement of the precipitator (sec)

XI - Number of charges on a given particle size at the start of a given increment or subincrement of the precipitator

X - Number of charges on a given particle size at the end of a given increment or subincrement of the precipitator

I - Index which runs over the different points specified for use in the Runge-Kutta scheme

NN - Number of points specified for use in the Runge-Kutta scheme

ECHARG - Elementary charge unit (coul)

SCHARG - Saturation charge number from the field charging equation

NUMINC - Number of increments in the Simpson's Rule integration over θ in equation (12)*

CONST - Value of the quantity $[2(K-1)a^3E_0/(K+2)]$ found in equation (12)* $[V\text{-}m^2]$

EZERO - Average electric field used for particle charging (V/m)

V - Value of the quantity $[e^2/4\pi\varepsilon_0 akT]$ found in equation (12)*

RSIZE - Radius of a particular particle (m)

ECONST - Value of the quantity $[3eE_0 a/kT(K+2)]$ found in equation (12)*

CMKS - Value of the quantity $[4\pi\varepsilon_0]$ found in equation (12)* $[\mathrm{coul}^2/\mathrm{nt}\text{-}\mathrm{m}^2]$

RR - Value of the quantity $[eE_0/kT]$ found in equation (12)* $[\mathrm{m}^{-1}]$

FCONST - Value of the quantity $[(K-1)eE_0 a^3/kT(K+2)]$ found in equation (12)* $[\mathrm{m}^2]$

FACTOR - Value of the quantity $[\pi\tilde{v}a^2/2]$ found in equation (12)* $[\mathrm{m}^3/\mathrm{sec}]$

COEFF - Value of the quantity $[bqs/4\varepsilon_0]$ found in equation (12)* $[\mathrm{m}^3/\mathrm{sec}]$

AFID - Average reduced free ion density for particle charging in a particular length increment $(\#/\mathrm{m}^3)$

T1 - Value of the charge-number rate to the particle surface at the point (XI,YI) multiplied by the stepsize H for use in the Runge-Kutta scheme

T2 - Value of the charge-number rate to the particle surface at the point (XI+H2, YI+T1/2) multiplied by the stepsize H for use in the Runge-Kutta scheme

T3 - Value of the charge-number rate to the particle surface at the point (XI+H2, YI+T2/2) multiplied by the stepsize H for use in the Runge-Kutta scheme

T4 - Value of the charge-number rate to the particle surface at the point (XI+H, YI+T3) multiplied by the stepsize H for use in the Runge-Kutta scheme

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR FUNCTION SUBPROGRAM RATE USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

ECHARG - Elementary charge unit (coul)

SCHARG - Saturation charge number from the field charging equation

NUMINC - Number of increments in the Simpson's Rule integration over θ (not used)

CONST - Value of quantity $[2(K-1)a^3E_0/(K+2)]$ found in equation (45) $[V\text{-}m^2]$

EZERO - Average electric field used for particle charging (V/m)

V - Value of the quantity $[e^2/4\pi\varepsilon_0 akT]$ found in equation (45)

RSIZE - Radius of a particular particle (m)

ECONST - Value of the quantity $[3eE_0a/kT(K+2)]$ found in equation (45) $[V\text{-}m^2]$

CMKS - Value of the quantity $[4\pi\varepsilon_0]$ found in equation (45) $[coul^2/nt\text{-}m^2]$

RR - Value of the quantity $[eE_0/kT]$ found in equation (45) $[m^{-1}]$

FCONST - Value of the quantity $[(K-1)eE_0a^3/kT(K+2)]$ found in equation (45) $[m^2]$

FACTOR - Value of the quantity $[\pi\tilde{v}a^2/2]$ found in equation (45) $[m^3/sec]$

COEFF - Value of the quantity $[bqs/4\varepsilon_0]$ found in equation (45) $[m^3/sec]$

AFID - Average reduced free ion density for particle charging in a particular length increment $(\#/m^3)$

NTIME - Instantaneous charging time (sec)

NUMBER - Instantaneous number of charges on a given particle size

INTGRL - Value of the integral appearing in equation (45)

NE - Negative of the instantaneous charge on a given particle size (coul)

T(I) - Roots of the Legendre polynomials of third order

A(I) - Gaussian weighting functions

THZERO - Maximum angle (θ_0) for field charging in radians

YFUC - The quadrature being computed

THETA - Values of the angle θ taken for the integration over θ in equation (45)

CTHETA - Value of the quantity [$\cos\theta$]

TCONST - Value of the quantity [$2(K-1)a^3E_0\cos\theta/(K+2)$] ($m^2$-V)

ECOS - Value of the quantity [$E_0 \cos\theta$] (V/m)

C1 - Value of the quantity [$q/4\pi\varepsilon_0E_0\cos\theta$]

CO - Value of the quantity [$(K-1)a^3/(K+2)$]

RZERO - Radial distance from the center of a given particle at which the total radial component of the electric field is zero (m)

ARG1 - Argument of the exponential function inside the integral in equation (45)

YVAL - Integrand of the integral in equation (45)

RATE1 - Contribtuion to the particle charging rate due to the second term in equation (45) [#/sec]

ARG3 - Argument of the exponential function in the third term in equation (45)

RATE2 - Contribution to the particle charging rate due to the third term in equation (45)

RATE3 - Contribution to the particle charging rate due to the first term in equation (45) [#/sec]

RATE - Total instantaneous charging rate to the entire surface of a given particle (#/sec)

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE ARCCOS USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

A - Numerator of the ratio A/B whose inverse cosine is to be determined

B - Denominator of the ratio A/B whose inverse cosine is to be determined

ACOS - Value of the quantity $[\cos^{-1}(A/B)]$ (radians)

RATIO - Value of the ratio A/B

T - Variable used to generate the different numerical coefficients in the series representation of the inverse cosine function

SUM - Sum of successive terms in the series representation of the inverse cosine function

TERM - A particular term in the series representation of the inverse cosine function

U - Variable used in the generation of the numerical coefficients in the series representation of the inverse cosine function

V - Variable used in the generation of the numerical coefficients in the series representation of the inverse cosine function

W - Variable used in the generation of the numerical coefficients in the series representation of the inverse cosine function

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE ZERO USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

C1 - Value of the quantity $[q/4\pi\varepsilon_0 E_0 \cos\theta]$ found in equation (52)*

C0 - Value of the quantity $[(K-1)a^3/(K+2)]$ found in equation (52)* $[m^3]$

RZERO - Radial distance from the center of a given particle at which the total radial component of the electric field is zero (m)

B - Value of the argument of the inverse cosine function found in equation (55)*

C - Value of the inverse cosine function found in equation (55)*

D - Factor multiplying the cosine function found in equation (12)*

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE CHGSUM USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

NVI - Indicator which specifies whether to base the electrical calculation on known voltages and currents or on calculated voltage-current characteristics

I - Index which runs over incremental lengths

II - Index which runs over subincremental lengths

OLDQF(J) - Value of field charge on the different particle sizes at the end of a given increment or subincrement (coul)

OLDQT(J) - Value of diffusion charge on the different particle sizes at the end of a given increment or subincrement (coul)

ITER - Counter which keeps track of the number of iterations which is limited by NITER

SOLDQF(J) - Value of field charge on the different particle sizes at the start of an increment which must be saved for the iteration procedure over subincrements in a given increment (coul)

SOLDQT(J) - Value of diffusion charge on the different particle sizes at the start of an increment which must be saved for the iteration procedure over subincrements in a given increment (coul)

E - Elementary charge unit (coul)

SCHARG - Saturation charge number from the field charging equation

SATCHG - Saturation charge for a given particle size from field charging theory (coul)

CHRFID - Average free ion density for particle charging (#/m^3)

U - Ion mobility adjusted for temperature and pressure (m^2/V-sec)

EPSO - Permittivity of free space ($coul^2/nt-m^2$)

TIMEF - Final value of time for particle charging (sec)

TIMEI - Initial value of time for particle charging (sec)

CF1 - Value of the quantity $[(N_0be/4\varepsilon_0)(t_f-t_i)]$ found in equation (15)*

CF2 - Value of the quantity $[1/(1-q_i/q_s)]$ found in equation (15)*

QF - Charge on a given particle size in a given increment or subincrement due to field charging (coul)

V - Value of the quantity $[e^2/4\pi\varepsilon_0akT]$ found in equation (15)*

ARG - Value of the quantity $[q_ie/4\pi\varepsilon_0akT]$ found in equation (15)*

RSIZE - Radius of a particular particle (m)

VAVC - Root mean square velocity of the ions (m/sec)

BC - Boltzmann's constant (J/°K)

TDK - Temperature of the gas in a given electrical section (°K)

QT - Charge on a given particle size in a given increment or subincrement due to diffusion charging (coul)

CNUMBR - Total charge number on a given particle size in a given increment or subincrement

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE PRTINC USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

NPRINT - Indicator which designates when to print certain sectionalized data

NSECT - Indicator which keeps track of which electrical section the calculation is in

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

ITL - Identifying label for the calculations

SLNGTH - Length of a particular electrical section (m)

A - Collection plate area of a particular linear electrical section (m^2)

VO - Applied voltage in a particular linear electrical section (V)

TC - Total current in a particular linear electrical section (A)

B - Wire-to-plate spacing in a particular linear electrical section (m)

AC - Corona wire radius in a particular linear electrical section (m)

WL - Total wire length in a particular linear electrical section (m)

CL - Total current per length of corona wire in a particular linear electrical section (A/m)

CD - Average current density at the plate in a particular linear electrical section (A/m^2)

ET - Average electric field in the deposited particulate layer in a particular linear electrical section (V/m)

SY - One-half the wire-to-wire spacing in a particular linear electrical section (m)

VG - Gas volume flow rate in a particular electrical section (m^3/sec)

VGAS - Gas velocity in a particular linear electrical section (m/sec)

TDK - Temperature of the gas in a given electrical section (°K)

P - Gas pressure in a particular linear electrical section (atm)

VIS - Gas viscosity in a particular linear electrical section (kg/m-sec)

U - Ion mobility adjusted for temperature and pressure (m^2/V-sec)

VAVC - Root mean square velocity of the ions (m/sec)

TMFP - Ionic mean free path multiplied by a factor (m)

W - Total weight of particles per second passing into a particular linear electrical section (kg/sec)

LINC - Length of the increments taken in a particular linear electrical section (m)

XPI - Overall mass collection efficiency per increment based on the estimated or design efficiency (%)

NVI - Indicator which specifies whether to base the electrical calculation on known voltages and currents or on calculated voltage-current characteristics

RIOVR - Ratio of the ionic space charge density to the total space charge density

ERAVG - Average electric field used for particle charging (V/m)

EPLT - Absolute value of the average electric field at the plate in a particular length increment (V/m)

AFID - Average reduced free ion density for particle charging in a particular length increment (#/m^3)

XCD - Average current density at the plate in a particular length increment (nA/cm^2)

ZMD - Interpolated mass median diameter of the collected particulate layer (m)

WT - Total weight of material per cubic meter of gas removed in all particle size bands in a given length increment (kg/m^3)

LTHICK - Thickness of the collected particulate layer in a particular increment of length (mm/min)

JPART - Current density due to particles in a particular increment of length (A/m^2)

JION - Current density due to ions in a particular increment of length (A/m^2)

I - Index which runs over incremental lengths

ROVRI - Ratio of the total space charge density to the ionic space charge density

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE PRTCHG USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

NCALC - Indicator which determines whether to use equation (12)* for particle charging or the sum of the classical field and diffusion charges

NEST - Indicator which specifies whether to use extensive calculations or estimation procedures in determining precipitator performance

JS - Index which is utilized in dividing the output data for particle charging into sets of eight columns each with a column for each particle size band

KS - Index which is utilized in dividing the output data for particle charging into sets of eight columns each with a column for each particle size band

NS - Number of different particle size bands in the inlet particle size distribution

DIAM(J) - Diameters of the different particle sizes (μm and m)

J - Index which runs over the different particle size bands

I - Index which runs over incremental lengths

NF - Number of increments taken along the length of the precipitator

NVI - Indicator which specifies whether to base the electrical calculation on known voltages and currents or on calculated voltage-current characteristics

NI - Number of subincremental lengths into which the incremental length is divided

N - Number of the subincremental strip having the maximum values of average electric field and current density

PI - Value of the constant π

EPSO - Permittivity of free space (coul^2/nt-m^2)

RAD(J) - Radii of the different particle sizes (m)

TMFP - Ionic mean free path multiplied by a factor (m)

EAVG(N) - Average electric fields for particle charging in subincremental lengths (V/m)

EPS - Relative dielectric constant of the particles

VRATIO - Ratio of the peak applied voltage to the average for use in particle charging

XDC(I,J) - Charge on each particle size at the end of each increment (coul)

QSATM - Saturation charge for a given particle size based on the last electrical section and the subincremental strip containing the largest values of average electric field and current density (coul)

YY(J) - Array containing the ratio of the charge on a given particle size to the saturation charge in the last electrical section for a given increment

QSAT(J) - Saturation charge for a given particle size based on the last electrical section and the average electric field for the entire section (coul)

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE ADJUST USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

NRUN - Indicator that specifies which set of nonideal conditions is under consideration

NS - Number of different particle size bands in the inlet particle size distribution

NS1 - Number of particle size bands plus one

NUMSEC - Number of linear electrical sections in the precipitator

NUMS1 - Number of electrical sections less one

TDK - Temperature of the gas stream in the last electrical section (°K)

PS(NUMSEC) - Pressure of the gas stream in the last electrical section (atm)

CONVF - Conversion factor which converts kg/ACM to mg/DSCM

NRAPDC - Counter which keeps track of the number of rapping puff particle size distributions that have been considered

X - Ideal, unadjusted overall mass collection fraction (or efficiency) [no units or %]

I - Index which runs over the different particle size bands

DXS(I) - Total number of particles removed per cubic meter of gas in each particle size band under ideal conditions and with no empirical corrections (#/m^3)

ONO(I) - Initial number of particles per cubic meter of gas in each particle size band (#/m^3)

EFESR - Ideal, unadjusted mass collection fraction for a given particle size

PCNT(I) - Percentage or fraction by mass in the inlet particle size distribution of the different size bands (% and decimal)

ARD50(J) - Rapping puff mass median diameters (μm)

ARSIGM(J) - Rapping puff geometric standard deviations

RMMD - Particular value of ARD50(J)[μm]

RSIGMA - Particular value of ARSIGM(J)

RPRCU(I) - Cumulative fraction by mass as a function of particle size for the rapping puff

RPCNT(I) - Percentages by mass in the different particle size bands for the rapping puff (%)

NONCK - Counter which keeps track of the number of sets of nonideal conditions of nonuniform velocity distribution and gas sneakage and/or particle reentrainment without rapping that have been considered

ASNUCK(K) - Fractions of gas sneakage and/or particle reentrainment without rapping

SNUCK - Particular value of ASNUCK(K)

AZIGGY(K) - Normalized standard deviations of the gas velocity distribution

ZIGGY - Particular value of AZIGGY(K)

AZNUMS(K) - Number of stages over which gas sneakage and/or particle reentrainment without rapping occur

ZNUMS - Number of stages over which gas sneakage and/or particle reentrainment without rapping occur for a particular case

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

Y - Adjusted overall mass collection fraction (or efficiency) under no-rap conditions (no units or %)

XEP - Adjusted mass collection fraction for a given particle size band under no-rap conditions

XMV(I) - Effective migration velocities for the different particle sizes under ideal conditions and with no empirical corrections (m/sec)

WY - Adjusted migration velocity for a given particle size under no-rap conditions (cm/sec)

VG - Gas volume flow rate in a particular electrical section (m^3/sec)

ATOTAL - Total collection plate area of the precipitator (m^2)

F1 - Correction factor for the migration velocity of a given particle size in order to account for nonuniform velocity distribution

F2 - Correction factor for the migration velocity of a given particle size in order to account for gas sneakage and/or particle reentrainment without rapping

WYS - Migration velocity of a given particle size corrected only for gas sneakage and/or particle reentrainment without rapping (cm/sec)

WYV - Migration velocity of a given particle size corrected only for nonuniform velocity distribution (cm/sec)

ZNLFF - Combined correction factor for nonuniform velocity distribution and gas sneakage and/or particle reentrainment without rapping

WYSV - Migration velocity of a given particle size corrected only for nonuniform gas velocity distribution and gas sneakage and/or particle reentrainment without rapping (cm/sec)

WUNCOR(I) - Unadjusted, ideal migration velocities for the different particle sizes (cm/sec)

EUNCOR(I) - Unadjusted, ideal mass collection efficiencies for the different particle sizes (%)

DIAM(I) - Diameters of the different particle sizes (μm and m)

PXS(I) - Number of particles per cubic meter of gas for a given particle size that are removed by the precipitator under adjusted, no-rap conditions (#/m^3)

IDC - Indicator which controls when the summation of outlet emissions over the different particle size bands will be performed

SPO - Total outlet emissions under adjusted, no-rap conditions (#/m^3)

SCPO - Total outlet emissions under rap + no-rap conditions (#/m^3)

IX - Indicator which determines when the total electrical length up to the last electrical section will be calculated

SCOREF - Overall mass collection efficiency under no-rap + rap conditions (%)

XY - Percentage by mass in a given particle size in the inlet particle size distribution (%)

PENTR - Percentage by mass of a given particle size that penetrates through the precipitator under adjusted, no-rap conditions (%)

PCTOT(I) - Percentage by mass in a given particle size band in the no-rap outlet emissions (%)

CLPTLS - Total electrical length of the precipitator excluding the last electrical section (m)

IS - Index which runs over the different linear electrical sections

LSECT(IS) - Number of length increments in the different linear electrical sections

LINCS(IS) - Lengths of the increments taken in the different linear electrical sections (ft)

NYX - Index which starts and terminates a loop in which the mass loss due to rapping and the mass leaving the precipitator under no-rap conditions are determined

XEFF - Overall mass collection fraction for either unadjusted, ideal or adjusted, no-rap conditions

NEFF - Indicator which determines whether the unadjusted, ideal or adjusted, no-rap efficiency is used to determine the mass reentrained due to rapping

EXPONT - Argument of the exponential function in equation (2) for either the unadjusted, ideal efficiency or the adjusted, no-rap efficiency

DL - Inlet mass loading (kg/m^3)

PL - Total electrical length of the precipitator (m)

XMELS - Mass entering the last section of the precipitator from either unadjusted, ideal or adjusted, no-rap calculations (kg/m^3)

XMCLS - Mass collected in the last section of the precipitator from either unadjusted, ideal or adjusted, no-rap calculations (kg/m^3 or mg/DSCM)

XMLLS - Mass leaving the last section of the precipitator from either unadjusted, ideal, or adjusted, no-rap calculations (kg/m^3)

NTEMP - Indicator which specifies whether the precipitator is cold or hot side

RAPLOS - Mass contained in the outlet emissions due to rapping (mg/DSCM)

YMELS - Mass entering the last section of the precipitator from adjusted, no-rap calculations (kg/m^3)

YMCLS - Mass collected in the last section of the precipitator from adjusted, no-rap calculations (kg/m^3 or mg/DSCM)

YMLLS - Mass leaving the last section of the precipitator from adjusted, no-rap calculations (kg/m^3)

DD - Mass density of the particles (kg/m^3)

RNS - Number of particles per cubic meter of gas in a given size band that are contained in the emissions due to rapping (#/m^3)

EFFWR - Mass collection fraction for a given particle size containing all corrections and adjustments

CRNP - Number of particles per cubic meter of gas in a given size band that are collected after rapping (#/m^3)

COREFF - Mass collection efficiency for a given particle size containing all corrections and adjustments (%)

WYP - Migration velocity for a given particle size containing all corrections and adjustments (cm/sec)

CPENTR - Percent penetration of a given particle size containing all corrections and adjustments (%)

CPCTOT(I) - Percentage by mass in a given size band contained in the no-rap + rap emissions (%)

SL - Number of particles per cubic meter of gas of a given particle size band exiting the precipitator under no-rap conditions ($\#/m^3$)

RAD(I) - Radii of the different particle sizes (m)

WSL(I) - Weight per cubic meter of gas of particles in a given size band exiting the precipitator under no-rap conditions (kg/m^3)

ENDPT(I) - Particle diameters in the inlet cumulative percent by mass distribution (μm and m)

DLD - Value of the quantity $[\Delta\log_{10}D]$ for a given particle size band in the size distribution histogram

DMDLD(I) - Value of the quantity $[\Delta M/\Delta\log_{10}D]$ for the different particle size bands in the outlet emissions under no-rap conditions (mg/DSCM)

RDMDLD(I) - Value of the quantity $[\Delta M/\Delta\log_{10}D]$ for the different particle size bands in the outlet emissions due to rapping only (mg/DSCM)

CDMDLD(I) - Value of the quantity $[\Delta M/\Delta\log_{10}D]$ for the different particle size bands in the outlet emissions under no-rap + rap conditions (mg/DSCM)

CCF(I) - Cunningham correction factor for the different particle sizes

ETAO - Estimated or design overall mass collection efficiency (%)

ZMMDI - Specified or fitted mass median diameter of the inlet particle size distribution based on a log-normal distribution (μm)

SIGMI - Specified or fitted geometric standard deviation of the inlet particle size distribution based on a log-normal distribution

NDIST - Indicator which specifies whether the user is to supply the inlet particle size distribution or the program is to calculate a log-normal distribution

GFIT - Linear-correlation coefficient obtained in the log-normal fit of the inlet particle size distribution

PRCUNR(I) - Cumulative percentage by mass as a function of particle size for the outlet emissions under no-rap conditions (%)

SUMNR - Summation over the different particle size bands of the percentage by mass contained in each size band for the outlet emissions under no-rap conditions (%)

ZMDL - Fitted mass median diameter of the outlet no-rap emissions based on a log-normal distribution (μm)

SIGMO - Fitted geometric standard deviation of the outlet no-rap emissions based on a log-normal distribution

ZGFIT - Linear-correlation coefficient obtained in the log-normal fit of the outlet no-rap emissions

COREFW - Precipitation rate parameter under no-rap + rap conditions (cm/sec)

WZ - Precipitation rate parameter under no-rap conditions (cm/sec)

PRCUC(I) - Cumulative percentage by mass as a function of particle size for the outlet emissions under no-rap + rap conditions (%)

SUMC - Summation over the different particle size bands of the percentage by mass contained in each size band for the outlet emissions under no-rap + rap conditions (%)

CZMDL - Fitted mass median diameter of the outlet no-rap + rap emissions based on a log-normal distribution (μm)

CSIGMO - Fitted geometric standard deviation of the outlet no-rap + rap emissions based on a log-normal distribution

CGFIT - Linear-correlation coefficient obtained in the log-normal fit of the outlet no-rap + rap emissions

M - Index which runs over the different particle size bands

NONID - Number of nonideal conditions of gas velocity nonuniformity and gas sneakage and/or particle reentrainment without rapping to be considered

NRAPD - Number of rapping puff particle size distributions to be considered

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE WADJST USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

DIAM(I) - Diameters of the different particle sizes (μm and m)

I - Index which runs over the different particle size bands

WY - Enters the subroutine as the unadjusted, no-rap migration velocity for a given particle size and leaves as the adjusted, no-rap migration velocity (cm/sec)

ONO(I) - Initial number of particles per cubic meter of gas in each particle size band (#/m^3)

PXS(I) - Number of particles per cubic meter of gas for a given particle size that are removed by the precipitator under adjusted, no-rap conditions (#/m^3)

ATOTAL - Total collection plate area of the precipitator (m^2)

VG - Gas volume flow rate in a particular electrical section (m^3/sec)

EFESR - Mass collection fraction for a given particle size under adjusted, no-rap conditions

CFACT(L) - Correction factors for the no-rap migration velocities of the different particle sizes

DCHECK(L) - Particle diameters corresponding to the different correction factors given by CFACT(L) [m]

L - Index which runs over the different values of CFACT(L) and DCHECK(L)

WFACT - Interpolated correction factor for the unadjusted, no-rap migration velocity of a given particle size

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE LNDIST USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

D50 - Specified or fitted mass median diameter of the inlet particle size distribution based on a log-normal distribution (μm)

SIGMAP - Specified or fitted geometric standard deviation of the inlet particle size distribution based on a log-normal distribution

PRCU(I) - Cumulative fractions by mass up to specified particle sizes

PCNT(J) - Fractions by mass contained in specified particle size bands

Y(K) - Values of the log-normal distribution function at different values of the independent variable for use in integrating the function over the specified size bands

Z(K) - Cumulative integrals resulting from the integration of the log-normal distribution function over a specified particle size band

AREA(J) - Amount of the distribution accumulated in a given particle size band

NS - Number of particle size bands

ENDPT(I) - Particle diameters specified for use in constructing the log-normal distribution histogram (μm)

NENDPT - Number of particle diameters specified for use in constructing the log-normal distribution histogram

PI - Value of the constant π

SIGMAZ - Value of the quantity $[\ln \sigma_\rho]$

N - Total number of particle size bands used in constructing the log normal distribution histogram

NINC - Number of points used in the Trapezoidal Rule integrations over the different particle size bands

ASUM - Value of the integration of the log-normal distribution function over the entire distribution

K - Index which runs over the NS different particle size bands specified by the user

J - Index which runs over the N different particle size bands used in the construction of the log-normal distribution histogram

X2 - Upper limit of integration for a given particle size band

X1 - Lower limit of integration for a given particle size band

DX - Stepsize taken for the Trapezoidal Rule integration of the log-normal distribution function over the different particle size bands

D - Value of the integration variable at different points in a given particle size band

SGT1 - Value of the quantity $[1/\sigma_z\sqrt{2\pi}]$

SGT2 - Value of the quantity $[2\sigma_z^2]$

I - Index which runs over the different points in a given particle size band in performing the Trapezodial Rule integration of the log-normal distribution function

SUM - Total fraction by mass contained in the histogram specified by the user

CHECK1 - Difference between 1 and the calculated total mass fraction contained in the histogram specified by the user

CHECK2 - Difference between 1 and the calculated cumulative fraction by mass up to the largest particle size specified by the user

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE QTFE USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

DX - Stepsize used in the Trapezoidal Rule integration scheme

Y(I) - Function values used in the integration scheme

Z(I) - Cumulative integrals resulting from the integration scheme

NINC - Number of points used in the integration scheme

SUM2 - Cumulative integral up to a given point in the integration scheme

DDX - One-half of the specified stepsize

I - Index which runs over the different points in the integration scheme

SUM1 - Cumulative integral up to the point prior to the point under consideration

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE LNFIT USED IN THE ELECTRISTATIC PRECIPITATOR PERFORMANCE MODEL

PRCU(I) - Known or calculated cumulative percentages supplied by the user (%)

D50 - Fitted mass median diameter based on a log-normal distribution (µm)

SIGMAP - Fitted geometric standard deviation based on a log-normal distribution

GFIT - Linear-correlation coefficient obtained in the log-normal fit

Z(I) - Natural logarithm of the actual particle diameters corresponding to the known or calculated cumulative percentages

Y(I) - Calculated natural logarithm of the particle diameters corresponding to the known or calculated cumulative percentages based on a true log-normal distribution

ENDPT(I) - Actual particle diameters corresponding to the known or calculated cumulative percentages (µm)

NENDPT - Number of particle diameters corresponding to the known or calculated cumulative percentages

NSTAG - Number of points used in the log-normal fit procedure

I - Index which runs over the different particle diameters corresponding to the known or calculated cumulative percentages

J - Index which sequences the points which are actually used in the log-normal fit

XY - Cumulative mass fraction less than a given particle size

XYY - Square root of the natural logarithm of the square of the reciprocal of XY

A - Y-intercept of the fitted straight line

B - Slope of the fitted straight line

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE CFIT USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

A - Y-intercept of the fitted straight line

B - Slope of the fitted straight line

R - Linear-correlation coefficient for the straight line fit

NSTAG - Number of data points that are fitted to the straight line

Z(I) - Values of the independent variable

Y(I) - Values of the dependent variable

XN - Running sum over the number of data points

SUMX - Summation over all data points of the values of the independent variable

SUMY - Summation over all data points of the values of the dependent variable

SUMXY - Summation over all data points of the values of the product of the independent and dependent variables

SUMXX - Summation over all data points of the values of the square of the independent variable

SUMYY - Summation over all data points of the values of the square of the dependent variables

I - Index which runs over the different data points

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE PRTSUM USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

ATOTAL - Total collection plate area of the precipitator (m^2)

VG - Gas volume flow rate in a particular electrical section (m^3/sec)

SCA - Specific collection area of the precipitator (m^2/m^3/sec)

VOSUM - Sum of the applied voltages in the different linear electrical sections (V)

CDSUM - Sum of the current densities in the different linear electrical sections (nA/cm^2)

NUMSEC - Number of linear electrical sections in the precipitator

LSECT(I) - Number of length increments in the different linear electrical sections

LINCS(I) - Lengths of the increments taken in the different linear electrical sections (ft)

I - Index which runs over the different linear electrical sections

VOS(I) - Applied voltages for the different linear electrical sections (V)

TCS(I) - Total current for the different linear electrical sections (A)

AS(I) - Collection plate areas for the different linear electrical sections (m^2)

AVO - Average applied voltage over the entire precipitator (V)

PL - Total electrical length of the precipitator (ft and m)

ACD - Average current density over the entire precipitator (nA/cm^2)

RHO - Resistivity of the collected particulate layer (ohm-m)

RHOCGS - Resistivity of the collected particulate layer (ohm-cm)

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

NRUN - Indicator that specifies which set of nonideal conditions is under consideration

SCOREF - Overall mass collection efficiency under no-rap + rap conditions (%)

ZMMDI - Specified or fitted mass median diameter of the inlet particle size distribution based on a log-normal distribution (μm)

SIGMI - Specified or fitted geometric standard deviation of the inlet particle size distribution based on a log-normal distribution

CZMDL - Fitted log-normal mass median diameter of the outlet particle size distribution under no-rap + rap conditions (μm)

CSIGMO - Fitted log-normal geometric standard deviation of the outlet particle size distribution under no-rap + rap conditions

SNUCK - Particular value of ASNUCK(JJ)

ZIGGY - Particular value of AZIGGY(JJ)

RMMD - Particular value of ARD50(II) [μm]

RSIGMA - Particular value of ARSIGM(II)

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE CMAN USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

NX - Number of grid points in the x-direction for the numerical calculations of electrical conditions

NX1 - Number of grid intervals in the x-direction for the numerical calculations of electrical conditions

NY - Number of grid points in the y-direction for the numerical calculations of electrical conditions

NY1 - Number of grid intervals in the y-direction for the numerical calculations of electrical conditions

SX - Wire-to-plate spacing in a particular linear electrical section (m)

AX - Interval size in the x-direction (m)

SY - One-half the wire-to-wire spacing in a particular linear electrical section (m)

AY - Interval size in the y-direction (m)

I - Index which runs over grid points in the x-direction

J - Index which runs over grid points in the y-direction

X - Value of x representing grid points (m)

Y - Value of y representing grid points (m)

VW - Electrical potential at the wire (V)

VCOOP(I,J) - Array containing the values of static potential at the different grid points (V)

NWIRE - Number of wires per electrical section per gas passage in a particular electrical section

M - Series sum in equation (1) is taken from -M to M

SUMX - Term in the sum for x-component of static electric field

SUMY - Term in the sum for y-component of static electric field

S1 - Parameter used in computing x-component of field at wire

S2 - Parameter used in computing y-component of field at wire

EXSUM - Parameter used in computing x-component of static field

EYSUM - Parameter used in computing y-component of static field

H3 - Sine function in equation (2)

F3 - Sine function in equation (1)

NUM - Sum in equation (1)

DENOM - Sum in the denominator of equation (2)

PI - Value of the constant π

E1 - Arguments for the hyperbolic cosine functions in equation (1)

F1 - Arguments for the cosine functions in equation (1)

G1 - Arguments for the hyperbolic cosine functions in the denominator of equation (2)

H1 - Arguments for the cosine functions in the denominator of equation (2)

E2 - Hyperbolic cosine functions in the denominator of equation (2)

F2 - Cosine functions in the denominator of equation (2)

G2 - Hyperbolic cosine functions in the denominator of equation (2)

H2 - Cosine functions in the denominator of equation (2)

TT - Argument for the logarithmic function in equation (1)

TB - Argument for the logarithmic function in the denominator of equation (2)

F - Logarithmic function in equation (1)

G - Logarithmic function in the denominator of equation (2)

E3 - Hyperbolic sine function in equation (1)

G3 - Hyperbolic sine function in equation (2)

ECX(I,J) - Array containing values of the x-component of the static field

ECY(I,J) - Array containing values of the y-component of the static field

X1(I) - Array containing x-components of grid points

Y1(J) - Array containing y-components of grid points

LTEST - Logical variable which determines when to use X1&Y1

NVII - Integer which determines when the approximations are used

EXO - Parameter used to compute x-component of field at wire

EYO - Parameter used to compute y-component of field at wire

LIST OF NECESSARY VARIABLES, DEFINITIONS, AND UNITS FOR SUBROUTINE EFLD3 USED IN THE ELECTROSTATIC PRECIPITATOR PERFORMANCE MODEL

IVCK - Indicator which terminates the calculation of points on the voltage-current whenever the specified applied voltage is reached and interpolated upon

VO - Specified operating applied voltage (V)

VSTART - Particular value of VSTAR(I) [V]

VW - Operating applied voltage corresponding to a specified current density (V)

AC - Radius of the corona wires (m)

RO - Radius of the corona wires (m)

TDK - Temperature of the gas stream (°K)

P - Pressure of the gas stream (atm)

RELD - Relative air density [$\delta = (T_0/T)(P/P_0)$]

ROC - Radius of the corona wires (cm)

RF - Roughness factor for the corona wires

EORO - Product of the corona starting electric field and the wire radius (V)

I - Index which runs over grid points in the x-direction

NX - Number of grid points in the x-direction for the numerical calculations of electrical conditions

J - Index which runs over grid points in the y-direction

NY - Number of grid points in the y-direction for the numerical calculations of electrical conditions

UEQ - Effective charge carrier mobility (m^2/V-sec)

NWIRE - Number of wires per electrical section per gas passage in a particular electrical section

VCOOP(I,J) - Array containing the values of static potential at the grid points (V)

V(I,J) - Array containing the value of the electric potential at each point in the grid during an iteration (V)

NPRNT - Indicator which specifies the unit number of the output device for printing data from the program

RHO(I,J) - Array containing the value of the space charge density at each point in the grid during an iteration (coul/m^3)

EX(I,J) - Array containing the value of the component of the electric field intensity perpendicular to the plates at each point in the grid during an iteration (V/m)

EY(I,J) - Array containing the value of the component of the electric field intensity parallel to the plates at each point in the grid during an iteration (V/m)

LTEST - Logical variable which determines whether a uniform grid spacing is used

NVII - An integer which determines whether measured operating conditions are used or a theoretical I-V curve is generated

ECX(I,J) - x-component of the static electric field

ECY(I,J) - y-component of the static electric field

X1(I) - Position of grid points in the x-direction

Y1(J) - Position of grid points in the y-direction

AX(I) - Grid point separation in the x-direction

AY(J) - Grid point separation in the y-direction

Z - Dummy arguments in statement functions COSH(Z) and SINH(Z)

R - Ratio R1/Sx

A1 - Constant = $\pi/2Sx$

B1 - Constant = $2J/b\varepsilon_0$

MOBILT(I,J) - Array containing the values of effective charge carrier mobility at the different grid points (m^2/V-sec)

PI - Value of the constant π

EPSO - Permittivity of free space ($coul^2/nt\text{-}m^2$)

START - Particular value of START1(I) [A/m^2]

SSTART - Initial value of START which is saved (A/m^2)

MAXS - Particular value of current density on the voltage-current curve (A/m^2)

NX1 - Number of grid intervals in the x-direction for the numerical calculations of electrical conditions

NY1 - Number of grid intervals in the y-direction for the numerical calculations of electrical conditions

SX - Wire-to-plate spacing in a particular linear electrical section (m)

AX - Interval size in the x-direction (m)

SY - One-half the wire-to-wire spacing in a particular linear electrical section

AY - Interval size in the y-direction (m)

IFINAL - Indicator which causes the calculation of successive points on the voltage-current curve to cease after IFINAL points

II - Index which runs over the different current densities to be used on the voltage-current curve

JI1 - Indicator which allows the initial increment size on current density in the calculation of the voltage-current curve to be changed after JI1-1 points are determined on the curve

DSTART - Particular value of START2(I) [A/m^2]

JI2 - Indicator which allows the second increment size on current density in the calculation of the voltage-current curve to be changed after JI2-1 points are determined on the curve

CSTART - Particular value of START3(I) [A/m^2]

BIR - Constant = $(B1)^{1/2}$

C1 - Constant = $B1Sy/\pi$

VWIR - Space charge contribution to the potential from points outside Sy

EXWIR - Space charge contribution to the x-component of the field from points outside Sy

EYWIR - Space charge contribution to the y-component of the field from points outside Sy

E1 - Independent variable associated with F1 in the method of false position

E2 - Independent variable associated with F2 in the method of false position

E3 - The latest estimate of the root of F in the method of false position

F1 - Negative value of the function in the method of false position

F2 - Positive value of the function in the method of false position

F - Function in the method of false position whose root determines when the specified operating voltage has been obtained

NW - Number of wires per electrical section per gas passage in a particular electrical section

R1 - Distance from the wire at which the analytic solutions are matched

SUM1 - A sum over the wires which contributes to the static potential at the wire

SIG1 - A sum over the wires which contributes to the static potential at the wire

RM - Floating point whole number used to avoid problems with mixed mode arithmetic

CH - Hyperbolic cosine function in the static potential expression evaluated at y = Sy

POT1 - A constant used in evaluating the static potential at the wire

SUMV - A sum over the space charge cylinders which contributes to the static potential at the wire

SUMW - Quantity = 2SUM1

SQON - A parameter to help simplify the coding of the mathematical expressions in the electrical solutions

SQOP - A parameter to help simplify the coding of the mathematical expressions in the electrical solutions

RNN - A parameter to help simplify the coding of the mathematical expressions in the electrical solutions

RNP - A parameter to help simplify the coding of the mathematical expressions in the electrical solutions

ARGR - A constant = $\pi R1/2Sx$

FAC1 - The expression represented by F in equation (22)

ACOS - The value of ARCCOS (Sy/R1) in equation (22)

DUM - The quantity shown in brackets in equation (22)

RLAM - The predicted value of static potential at the wire

RAD - A parameter used to simplify the coding of the mathematical expressions in the electrical solutions

RASX - A parameter used to simplify the coding of the mathematical expressions in the electrical solutions

RAR1 - A parameter used to simplify the coding of the mathematical expressions in the electrical solutions

RONSP - A parameter used to match the charge density profiles at x = R1

CLAM - A parameter used to match the x-components of the electric field at x = R1

WLAM - A parameter used to specify the effective value of space charge density outside the region of Sy

VNAUT - A parameter used to match the potentials at x = R1

VT - The total potential at the wire

ICOUNT - An integer which counts the number of tries to match the specified operating voltage in the method of false position

I11 - Do loop parameter which increments x over the grid points

I12 - Do loop parameter which increments y over the grid points

SQRN - Parameter which simplifies coding the mathematical expressions in the electrical solutions

SQRP - Parameter which simplifies coding the mathematical expressions in the electrical solutions

SQXN - Parameter which simplifies coding the mathematical expressions in the electrical solutions

SQXP - Parameter which simplifies coding the mathematical expressions in the electrical solutions

ARGX - Quantity = $\pi x/2Sx$

ARGY - Quantity = $\pi y/2Sy$

RAXY - Parameter which simplifies coding the mathematical expressions in the electrical solutions

RASXY - Parameter which simplifies coding the mathematical expressions in the electrical solutions

RAR1Y - Parameter which simplifies coding the mathematical expressions in the electrical solutions

COSHY - Hyperbolic cosine evaluated at $\pi y/2Sx$

SINHY - Hyperbolic sine evaluated at $\pi y/2Sx$

CX - Cosine function evaluated at $\pi x/2Sx$

VXYJ - Space charge contribution to the potential

EXJ - Space charge contribution to the x-component of the electric field

EYJ - Space charge contribution to the y-component of the electric field

RHOJ - Space charge density

SUMEX - A sum over space charge cylinders which contributes to the x-component of the electric field

SUMEY - A sum over space charge cylinders which contributes to the y-component of the electric field

COSX - Cosine function evaluated at $\pi x/2Sx$

SINX - Sine function evaluated at $\pi y/2Sy$

COSHN - The hyperbolic cosine function containing the negative sign in equations (8) - (13)

COSHP - The hyperbolic cosine function containing the positive sign in equations (8) - (13)

SINHN - The hyperbolic sine function containing the negative sign in equations (10) - (13)

SINHP - The hyperbolic sine function containing the positive sign in equation (10)

DENON - Quantity = $\text{COSHN}^2 - \text{COSX}^2$

DENOP - Quantity = $\text{COSHP}^2 - \text{COSX}^2$

TERMV - Logarithmic contributions to the potential from space charge at a point outside Sy

TEREX - Quantity used in summing the contributions to the x-component of the field from space charge outside Sy

SUMEX - The sum contributing to the x-component of the field due to space charge outside Sy

TEREY - Quantity used in summing the contributions to the y-component of the field from space charge outside Sy

SUMEY - The sum contributing to the y-component of the field due to space charge outside Sy

OLDV(I,J) - Array containing the value of the electric potential at each point in the grid during the previous iteration (V)

OLDRO(I,J) - Array containing the value of the space charge density at each point in the grid during the previous iteration (coul/m^3)

CDNSTY(I,J) - Array containing the value of current density at each point in the grid (A/m^2)

ACDNTY - Average current density at the plate (A/m^2)

EPLT - Sum of the values of the electric field intensity at the plate (V/m)

AEPLT - Average electric field at the plate (V/m)

EBD - Electrical breakdown strength of the gas near the collection electrode or the collected particulate layer (V/m)

OLDVW - The value of applied voltage at the point prior to the one under consideration (V)

OLDCD - The value of average current density at the plate at the point prior to the one under consideration (A/m^2)

NEC - Indicator which determines whether or not the average current density, average electric field, and average electric field at the plate are to be calculated in the subincremental lengths

K - Index which sequences the grid strips in the basic area for which the calculations are performed

RSUM - Average charge number density in a particular grid strip ($\#/m^3$)

ESUM - Average electric field intensity in a particular grid strip (V/m)

EAVGS(K) - Array containing the average electric field intensities in the different grid strips in the basic area for which the calculations are performed (V/m)

CHFIDS(K) - Array containing the average charge number densities in the different grid strips in the basic area for which the calculations are performed ($\#/m^3$)

NYY - Index which renumbers the grid strips so that by symmetry the area covered by the half-wire spacing which was not considered in the calculations can be taken into account

EAVG(L) - Array containing the average electric field intensities in the different grid strips which cover an area between successive wires (V/m)

CHFID(L) - Array containing the average charge number densities in the different grid strips which cover an area between successive wires ($\#/m^3$)

L - Index which runs over and numbers the first (NY-1) grid strips in a given wire-to-wire spacing

KK - Index which runs over the different grid strips in the basic area for which the calculations are performed

M1 - Number of the first grid strip in the last (NY-1) grid strips in a given wire-to-wire spacing

M2 - Number of the last grid strip in a given wire-to-wire spacing

M - Index which runs over and numbers the last (NY-1) grid strips in a given wire-to-wire spacing

LL - Index which sequences the grid strips in the basic area for which the calculations are performed

NN - Index which runs over points in the y-direction

ECOLLS(LL) - Array containing the average electric field intensity at the plate in the different grid strips in the basic area for which the calculations are performed (V/m)

L1 - Index which renumbers the grid strips so that by symmetry the area covered by the half-wire spacing which was not considered in the calculations can be taken into account

ECOLL(L) - Array containing the average electric field intensity at the plate in the different grid strips which cover an area between successive wires (V/m)

L2 - Index which runs over the different grid strips in the basic area for which the calculations are performed

I1 - Number of the first grid strip in the last (NY-1) grid strips in a given wire-to-wire spacing

I2 - Number of the last grid strip in a given wire-to-wire spacing

I - Index which runs over and numbers the last (NY-1) grid strips in a given wire-to-wire spacing